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X-Ray Inspection of Aluminium Alloy Castings and Forgings

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Information obtained from X-ray inspection may be used to modify design or technique involved in production of castings or forgings, and may be profitably employed at an early stage in the manufacturing process.

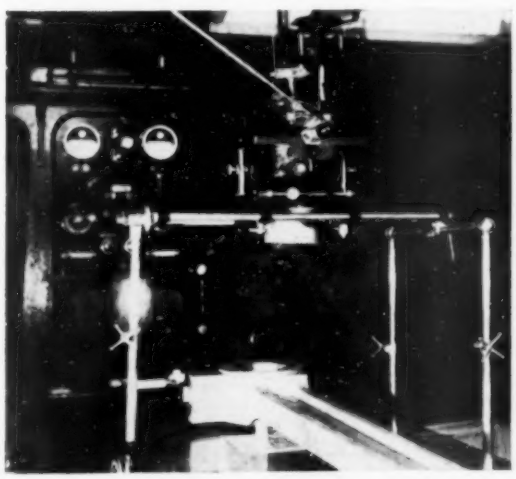


Fig. 1.—X-raying the "Big End" of a Locomotive Connecting-rod made of Forged "Y" Alloy 5⅛ in. thick.

SINCE its year of discovery in 1895 the X-ray has been mainly applied in medical and surgical practice. Fractures and abnormalities occurring in the human body are investigated, and some diseases treated by these penetrating rays. The Great War showed the way to a commercial field when X-rays were used for the examination of wooden aeroplane structures and instruments of warfare, such as hand-grenades, fuses, and cartridges. The combative branch of X-ray work involved the inspection of iron and steel, and the Woolwich Arsenal, in this country, and the Watertown Arsenal, in America, developed the technique and designed apparatus for the radiography of such comparatively heavy metals. We, indeed, live in an iron age, but with the advent of the motor-car and the aeroplane, and the concomitant discovery of light aluminium alloys—"as strong as steel and one-third the weight"—an aluminium era is being gradually introduced. The high speed records of our time have been made possible by the use of aluminium alloys in car and aeroplane construction.

I have been engaged in the X-ray inspection of three important aluminium alloys: Hiduminium, "Y" alloy, and "R R" alloys. These alloys have been variously employed. In the manufacture of brake shoes for Capt. Campbell's speed car, for instance, R R 53 alloy was successfully used to supplant steel, and it is interesting to note that when slowing down from the maximum speed of 246 miles per hour these brake shoes were in constant close application for a distance of four miles. Last year's winner of the Schneider Trophy, the Supermarine Rolls-Royce S 6, and Lord Wakefield's speed-boat, Miss England II., had all the aluminium engine parts made of one or other of the R R alloys. Recently, I X-rayed a locomotive connecting rod—one of a series—made of forged Hiduminium "Y" alloy.

This article deals with the direct radiographic inspection of such "high-duty" alloys. It is not proposed to deal with the other type of X-ray investigation, namely, the spectroscopic or diffraction method, which, it may be pointed out, is of metallurgical value in showing: (1) Whether a condition of internal strain exists in a given section of forged metal; (2) the elimination of such strain by suitable heat-treatment; (3) the uniformity of structure and distribution of strain in a given casting.

In order to take X-ray photographs (or radiographs) a high-voltage generator capable of delivering unidirectional current at a pressure of 50,000 to 180,000 volts is necessary. This current is passed through an X-ray tube, and the X-rays emerging from the target are directed through the object for inspection, and on to a photographic film placed in a casette or holder on the opposite side. The degree of penetrability of the X-rays produced at any given moment is dependent upon the peak of the voltage applied to the X-ray tube. Thus, at 50,000 volts (peak) 1 in. of alloy can be penetrated, at 90,000 volts 4 in. of alloy, at 130,000 volts 7 in., and at 180,000 volts 1 ft. The voltage should be adjusted according to the thickness of the part to be investigated. The time of the exposure is dependent upon four factors:—(1) The thickness of the object; (2) the applied voltage; (3) the number of milliamperes passing through the X-ray tube; and (4) the distance of the X-ray film from the target of the X-ray tube.

At the present day fast double-coated films are made for X-ray purposes. The film is placed between two fluorescent screens in a light-tight holder called a casette. The object to be X-rayed rests upon the casette throughout the period of the exposure. Development of the film takes place in developing tanks in a dark room. It is found that clear definition is best obtained when (*a*) the lowest voltage suitable for adequate penetration is employed, and (*b*) when the film is kept between fluorescent screens during the exposure.

When the X-rays meet a given object some of the rays are absorbed, others are scattered, and the remainder emerge on the other side undeviated from their original path. Blow-holes or cracks allow more of the rays to

pass, and an increased darkening takes place at corresponding points of the film. Dense inclusions cause a greater absorption of the rays, and light areas, corresponding to such inclusions, are seen in the fully developed film. The scattered rays on meeting the film are liable to blur the original detail produced by the non-deviated rays. The thicker the object is, the greater will be the quantity of scattered radiation, with consequent loss of clarity in definition. From the commercial point of view, useful X-ray examination can be carried out up to a thickness of 9 in. of alloy. Apparatus for this purpose is illustrated in Fig. 1 which shows its application for X-raying the big end of a connecting rod made of forged Y-alloy $5\frac{3}{4}$ inches thick.

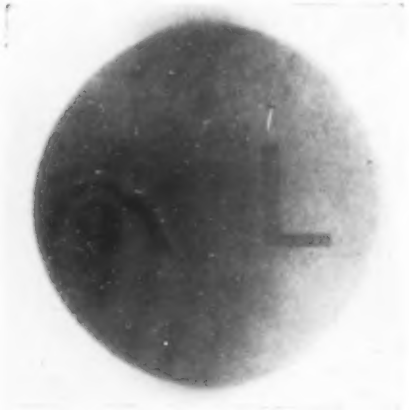
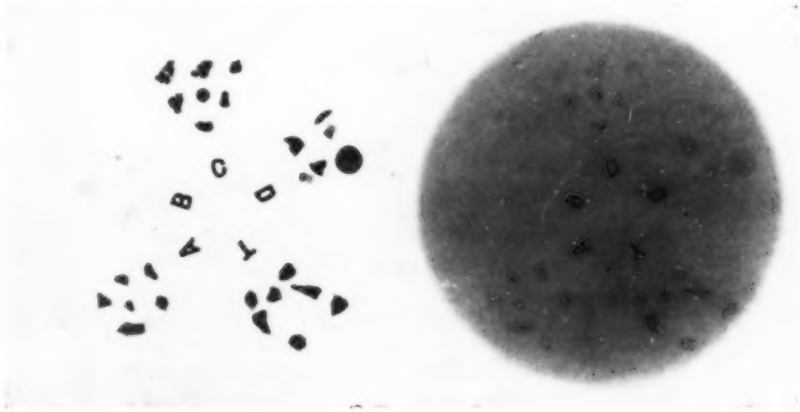


Fig. 2.—Shadows shown by Lead Letters X-rayed through 1 ft. of " Y " Alloy.



Figs. 3 and 4.—X-ray Photograph of Sample Inclusions A = Chromium, B = Furnace Slag, C = Cobalt, D = Nickel, T = Titanium, through $\frac{3}{4}$ and 3 inches of " Y " alloy, respectively.

In order to discover whether a given solid block of alloy has been penetrated by any period of exposure to X-rays, it is usual to place lead letters, about 2 mm. thick, between the specimen and the film. Thus, in Fig. 2, two lead letters, R and L, cast shadows when X-rayed through 1 ft. of " Y " alloy. Lead, however, is not a likely inclusion in the aluminium-alloy industry, and experiments have been carried out with such probable inclusions as titanium, chromium, nickel, cobalt, and furnace slag. The " inclusions," which varied in size from $\frac{1}{16}$ in. to $\frac{3}{16}$ in. in thickness, were X-rayed through different thicknesses of alloy. It was found that the furnace slag inclusions could be distinguished up to a thickness of 2 in. of alloy, but no farther. This fact will be appreciated when it is stated that the average thickness of the piston-head of an aero-engine is $\frac{3}{8}$ in. All the other inclusions (titanium, chromium, cobalt, and nickel) cast shadows which were clearly distinguishable up to a thickness of $3\frac{1}{2}$ in. of alloy. At 4 in. these shadows were almost, but not totally, obscured (Figs. 3 and 4).

Blow-holes are frequently to be found in aluminium-alloy castings, but very rarely in forgings. When present they can be very easily demonstrated. Several experiments were carried out with holes drilled into blocks of " Y " and R R 50 alloy. Blow-holes of three sizes, $\frac{1}{16}$ in., $\frac{1}{4}$ in., and $\frac{1}{4}$ in. in diameter, could be clearly distinguished up to a thickness of 4 in. of alloy. Beyond this thickness detail was gradually lost. A reproduction of an X-ray photograph showing these three blow-holes taken through a thickness of 4 inches is illustrated in Fig. 5. A blow-hole 1 in. in diameter showed up well in an X-ray picture taken through 8 in. of alloy (Fig. 6). This blow-hole, however, did not show up when X-rayed through 1 ft. of alloy, using the same technique as for the radiography of the lead letters described above (Fig. 2). Hair-like shrinkage cracks can be revealed by careful radiography; these are, however, difficult to reproduce in this article although visible on the photograph. A finished piston is often scrapped on account of minute aluminium-oxide surface specks. These specks cannot be demonstrated by X-rays unless they penetrate beneath the surface of the piston for a distance of over $\frac{1}{10}$ in.

In the aluminium-alloy industry X-ray inspection should be employed more often with castings than with forgings, simply because flaws occur more frequently in the former than in the latter. A single radiograph gives more information

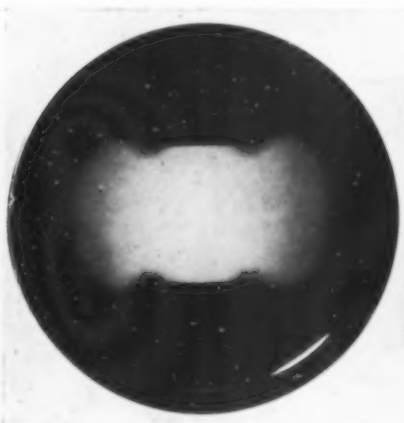


Fig. 7.—Aeroplane Piston, showing structure of thinnest part of the Head—$\frac{3}{8}$ in. thick.

Fig. 8.—Side View of Aeroplane Piston.

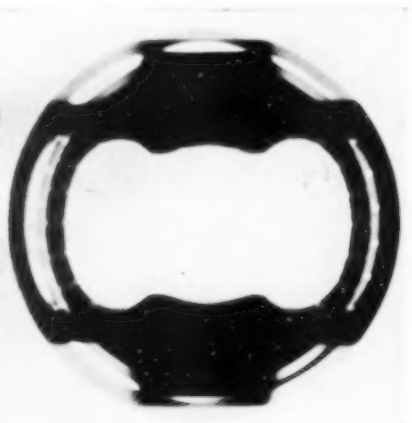


Fig. 9.—Aeroplane Piston, to show structure of Rim.

concerning the presence of blow-holes and inclusions than any number of sectionings, and the destruction of a specimen which might otherwise be thoroughly fit for service is avoided. Every new type of production casting to be used to withstand stress should be X-rayed in at least two planes, and then if found to be faulty sectioned at the defective places. The information thus obtained can be used to alter either the design or the situation for the runners and risers. The correct interpretation of the radiographs requires some experience in the study of X-ray pictures.

Where high machining costs may be followed by the eventual rejection of a finished part owing to the discovery of a crack, blow-hole, or sandy inclusion, X-ray inspection

Fig. 5.—Blow-holes $\frac{1}{4}$, $\frac{1}{8}$ and $\frac{1}{16}$ in. X-rayed through 4 in. of R.R. 50 Alloy.

may be profitably employed at an early stage of the manufacturing process. Supercharger impellers afford a useful instance. When human safety or reputation is in question the cost should not figure.

In conclusion, a comparison with the technique employed in the X-raying of iron and steel objects may be instructive. At the present moment it is not practicable to X-ray steel objects to a greater depth than 4 in. A tube has, however, been recently designed and constructed in France to take 400,000 volts without suffering damage. This will probably increase the range of penetrability of iron and steel to 6 in. The X-ray workers on iron and steel must, of necessity,

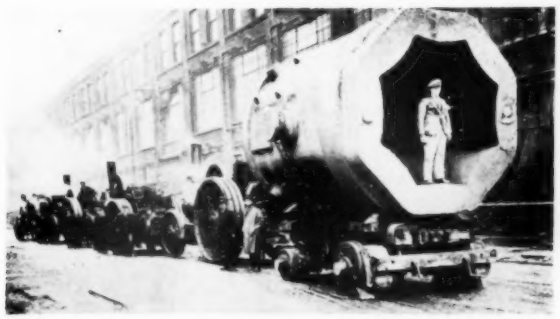
Fig. 6.—A Blow-hole 1 in. in dia. X-rayed through 8 in. of "Y" Alloy.

be shielded from the scattered rays by large lead screens 4 mm. thick. In fact, with voltages above 150,000, it is best to house the entire apparatus in a lead-lined room, keeping the operator outside. In X-raying aluminium alloys care also is necessary, but not to such a degree. The voltages most frequently employed are in keeping with those used in general radiographic work in hospitals. Here the worker keeps a fair distance away from the X-ray tube, and is shielded by a leaded screen from the scattered rays. It is only rarely that the 150,000-volt mark is exceeded in X-raying aluminium alloys (objects thicker than 6 in.), and exposures are comparatively short. When 180,000 volts are applied to the tube, it takes 75 secs. for a current of 2 milliamperes to give adequate X-ray penetration of 1 ft. of alloy. By contrast, exposures of half an hour are necessary when $3\frac{1}{2}$ in. of steel are being X-rayed with an applied voltage of 200,000.

I am indebted to Mr. W. C. Devereux, managing director of High Duty Alloys, Ltd., for permission to publish this article.

AN INDUSTRIAL ADVANCE.

The large ingot-mould illustrated has just been delivered by road to the Vickers works of the English Steel Corporation, at Sheffield. Made by the Brightside Foundry and Engineering Company, it weighs 112 tons, and was lifted on to a truck drawn by 5 traction engines, by a crane having a capacity of 150 tons. In this mould, ingots can be produced of a size exceeding any previously made in this country. The hollow forging, of which we show a photograph, is for high-pressure chemical vessels weighing 60 tons, and large electrical rotors weighing well over 100 tons, and is typical of the forgings for the making of which ingots from this mould will be used. At first sight, it would



Large Ingot Mould.

appear that the ingots made are much larger in size than seem necessary for the size of forging required ; but it must be remembered that quite a large part of the ingot is removed as waste, when making very high grade forgings. The top end of the ingot in particular is discarded, to remove all piping. The English Steel Corporation specialises in large forgings of this kind, but its work is by no means confined to these only, for it also produces steel of the highest grade for aeroplane, motor-car and motor-boat parts. As an example of quality of material, it is of interest

High-pressure Chemical Vessel Forging.

to mention that the crankshaft, gears, axles and frame of the "Blue Bird" were produced by this Corporation, as also were the crankshafts, rudders, and propeller of "Miss England II."

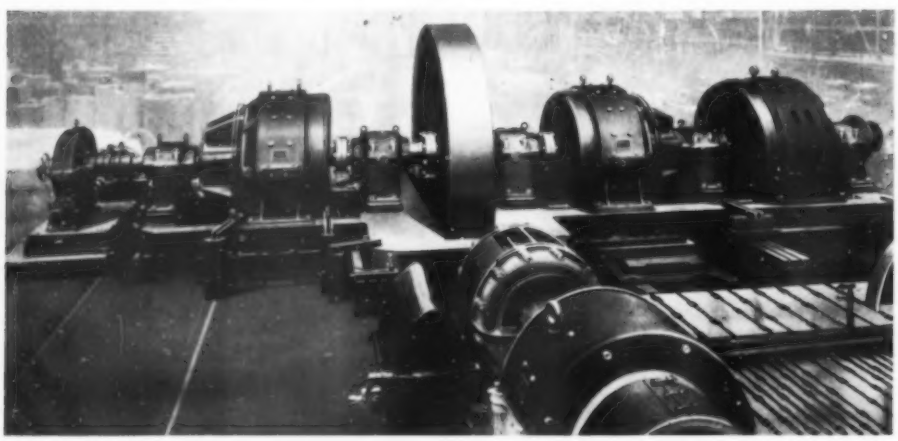
Welding Engineers' Award.

At a meeting of the Institution of Welding Engineers on February 12, the name was announced of the winner of the Operatives' Prize Competition, 1930, organised by the Institution. After the presentation of the prize, gold medal, certificate, and silver medals, the prize-winner, Mr. E. Storey, of Billingham, read his paper. It was entitled : "Welding Practices and Methods based on My Own Experiences," and discussed a number of jobs done in the works of Messrs. Synthetic Ammonia and Nitrate, Ltd., by which firm Mr. Storey is employed. It was illustrated by lantern slides, and was followed by a discussion.

Developments in Blast Furnace and Rolling Mill Equipments.

IT is logical to assume that increased competition in industry, resulting from depression, should have a considerable influence on technical progress. Keen competition causes new conditions to arise, and even the most established firms are forced to realise the necessity of preparing to meet them more effectively. Progress is only possible by improving the technique employed in manufacturing processes and taking advantage of the best research facilities available. These are necessary to effect all possible economy in production while maintaining or increasing the quality of the product. To this end many notable achievements have been accomplished in mechanical progress from the raw material to the finished article, but probably the most numerous of these improvements are associated with the manufacture of semi-finished materials. Considerable reorganisation has been effected, or is in progress, in regard to blast furnace equipment, as well as sheet and rolling mills, with a view to extending the capacities of these plants. In these developments the use of electricity is having a very important influence. The improved designs in motors and controlling devices are such that entire mills are now electrically equipped and operated, while blast furnace operations are being expedited as a result of the increasing use of electrical appliances.

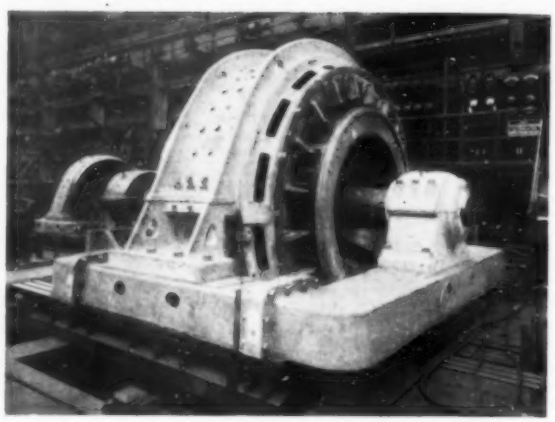
Among recent developments, not the least important are the electrical equipments installed by Metropolitan-Vickers Electrical Co., Ltd., the largest of which is a 2,300 h.p. equipment for Messrs. Steel, Peech and Tozer, Ltd., of Sheffield. This installation drives a 27-in. reversing intermediate mill, and is designed to deal with peak loads of 7,040 h.p. It is arranged with Ward Leonard control, and is provided with a foot-operated master controller to enable the driver to work both the front and back live roller gear, and also the screw gear, at the same time.



Flywheel Motor Generator Set for Messrs. Steel, Peech & Tozer, Ltd.

Other installations include a number of tyre mill equipments with Ward Leonard control. The most important of these is an equipment with 800 h.p., 500 h.p., and 120 h.p. motors for Messrs. Taylor Bros., of Trafford Park; a 600 h.p. equipment for the Monkbridge Iron Co.

Among the equipments in course of erection, the largest installation is for the Whitehead Iron and Steel Co, Newport. It is for a 12-in. merchant mill, comprising a three-stand roughing mill driven by a 700-h.p. motor through gearing; a four-stand intermediate mill driven by a 1,500 h.p. motor through gearing; and four separate finishing stands, each driven by a 700-h.p. motor direct. Each of the main motors will be started up by means of contactor control equipments, and controlled from a central control desk, situated in a convenient position so that the operator can see the whole of the mill floor and the operation of the individual motors.

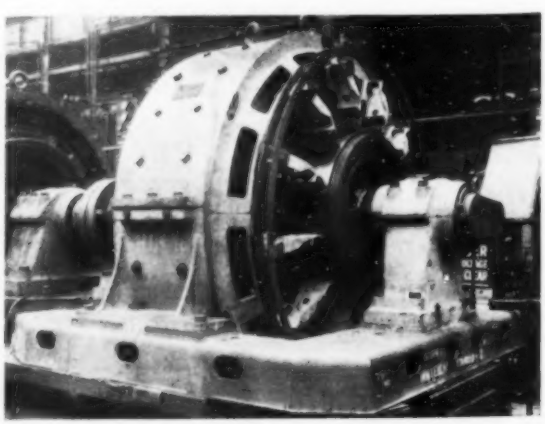


2,300-H.P. D.C. Motor for Messrs. Steel, Peech & Tozer, Ltd.

Other equipments approaching completion include a 200-h.p. D.C. motor and rotary converter set for a 325 mm. merchant mill in Spain, a 750-h.p. induction motor for a 25-in. three-high cogging mill of Messrs. Andrews Toledo, Ltd., Sheffield, and a 150-h.p. induction motor for a two-high merchant mill for Messrs. J. Willey and Sons, Ltd., Sheffield.

Installations of blast-furnace hoist equipments include a 110-h.p. equipment with Ward Leonard control for Messrs. Bolckow Vaughan and Co., Ltd., an equipment with contactor control being supplied through Messrs. John Millburn for the Darwen and Mostyn Iron Co., Ltd., North Wales, and a set of D.C. equipments with automatic straight control, this being the fifth set to be installed at the Stanton Iron Works by the Metropolitan-Vickers Co. These equipments are completely automatic throughout, including automatic control of hoists, large and small bell operating gear and revolving distributor gear, each operation being sequence-controlled so as to reduce delays to a minimum and to ensure even distribution of the material in the furnace, and is readily adaptable to existing furnace gear employing revolving hopper distribution.

700-H.P. 500-volt D.C. Motor for the Whitehead Iron and Steel Co.



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SCIENTIFIC KNOWLEDGE IS ESSENTIAL TO PROGRESS.

THE suggestion made by Mr. R. T. Tizard, C.B., A.F.C., at the annual dinner of the Institute of Metals, that there may be a surplus of scientific knowledge, was rightly, in our opinion, repudiated by the President, Dr. R. Seligman. However much human thought may sway, and in many respects repeat that of past ages, there is always a steady and irresistible advance in that which sets the framework of our individual and social existence—the intimate knowledge of the world in which we live and its capabilities, all of which can be summed up by the word science. The rate at which progress is made is variable, due to the varying degrees of success in adding to the store of knowledge or in making adequate use of that which exists between one age and another; but the totality of knowledge is ever on the increase.

Science is ever changing the world in which we live by making us more fully acquainted with the properties and potentialities of that which we find there. The uncivilised people see similar stones and plants and streams as we do, but they mean so much less to them than they do to us. Science has revealed to us that everything in this world has special potentialities, of which we may avail ourselves as the need arises, and as we apply scientific knowledge successfully.

We cannot foretell the future, but the increasing population of the world, together with the advance of civilisation, are presenting problems that can only be solved adequately by persistent scientific research. Whatever may be the opinions of some sections of the community in regard to the simple life, they desire to maintain the scientific progress that is establishing ascendency over disease, aiding in the production of food necessary, economising motive power, and reducing the limitations of the products capable of being obtained from the raw materials of the world. Millions still require the simplest rudiments of civilisation, and science must come to the help of industry to facilitate production, in order that essential requirements may be, as Sir Hugh Bell has suggested, good, cheap, and abundant.

We continue to tolerate waste in the burning of raw coal, for instance, though gradually the fact is being appreciated that by the concentration of heat, light, and power supply, in close concert with coal distillation, together with restrictions on the present methods of use, much greater value can be obtained from our most valuable raw material. Recent investigations have shown considerable progress in the extraction of oil from coal, and they apparently indicate that only the fringe of its potentialities in this respect have been touched.

In the metallurgical field, with which we are more concerned, research has enabled investigators to discover new alloys, or to improve the manufacture of known metals and alloys. One of the most outstanding of the more recent discoveries in alloys is that of corrosion-resisting steels, but to say that we have reached finality in the development of these steels or in the technique of their manufacture would be absurd. The possibilities of this range of alloys are enormous, but many problems in regard to forging and other operations are being investigated, and as research proceeds difficulties are gradually being smoothed out.

Research work on the physical chemistry of steel-making has covered a series of fundamental studies on the action of oxygen in liquid steel and the application of the results to open-hearth operation.

It can be appreciated that keen competition sharpens the need for exploring every avenue likely to give better and cheaper products, and it is largely due to industrial depression that additional efforts are being made to alleviate distress by concentrating on the development of new industries, on problems likely to cheapen the cost of production and facilitate increased consumption. Although the majority of large works are now equipped with laboratories adequately staffed for dealing with the routine work of analysing and testing and for investigating operating plant and manufacturing problems, only in exceptional instances is there time for prolonged research. In many cases the problems are of such magnitude in their effect on an industry that the necessary scientific work involved cannot be satisfactorily carried out by an industry unaided. Under such conditions the State has an interest in assisting the solution of problems affecting industry and in fostering the development of the results of research. This is the main purpose of the Department of Scientific and Industrial Research, which is very active in mobilising available scientific forces in the support of industry. Much of this work is being done through committees appointed by the Department, as in the case of the Steel Structures Research Committee, which has been investigating methods of stress analysis, measurement of loads, and the examination of strains and stresses in existing buildings, and is at present engaged in an investigation into electric welding for structural purposes. Much valuable research work is carried out at the National Physical Laboratory and at the Woolwich Research Department, while research associations like the British Non-Ferrous Metals and the British Cast Iron Research Associations, in addition to activity in their scientific work, give considerable attention to the practical application of the results of research.

Both these associations are supported by the Department of Scientific and Industrial Research, and the extent of the financial support is dependent upon the subscriptions income. The Non-Ferrous Metals Research Association has recently been centralised in London, where the research laboratories are now in an active stage of equipment. This Association has done some excellent research work, of which the application of alloys intended for high temperatures is an outstanding example. This work has been continued at the National Physical Laboratory, and important advances have been made in the development of alloys of

The fourth article by Francis W. Shaw, M.I.P.E., on "The New Alloys and Machine Tool Design"; the third article by F. W. Rowe, B.Sc., M.I.M.M., on "Castings for Bronze Gears"; as well as many other articles, have been unavoidably held over.

nickel with chromium. During recent years, this Association has given much attention to the evolution of gases by metals on solidification, and researches are in progress on gases in copper, as well as a wide range of other investigations in the non-ferrous field.

The British Cast Iron Research Association has a wider scope than its name implies. It covers the whole of the technical side of the founding industry, the raw materials as well as the products. It is not possible to refer to all the complex problems investigated by this association, but of recent work mention may be made of the work on sand and refractories by the Association's staff in the Refractories Department of the University of Sheffield, the development of the balanced blast cupola, as well as further investigations on high-silicon heat-resisting cast irons.

In addition to research associations, each of the various industries have their own organisations, which provide a means of communication to its members on matters bearing upon their respective interests, arrange meetings in order to discuss practical and scientific problems relating to manufactures within the scope of each, and generally providing facilities for the advancement of both practical and scientific knowledge. The recent general meeting of the Institute of Metals is a typical instance. At this meeting the results of some valuable research work were presented, and are referred to elsewhere. The Iron and Steel Institute, the Institution of Mechanical Engineers, the shipbuilding institutions, to mention but a few, are concerned in spreading information capable of being used to meet modern industrial demands. Some of these institutes undertake research work and appoint suitable committees with that object. The Institution of Mechanical Engineers, for instance, has a number of investigations in progress, while the North-East Coast Institution of Engineers and Shipbuilders has appointed a committee to consider the desirability of defining the term "fatigue" as used in connection with the failure of steel castings and forgings.

Although we cannot agree that there can be too much scientific knowledge, there is a danger that valuable research work may not be developed adequately. Unless the maximum knowledge is imparted and brought into line with industry with a view to its resuscitation and maintenance on a high standard of efficiency, much valuable time spent on scientific research may be wasted. Fortunately the various organisations take a very serious view of this aspect, and are doing excellent work in the development of research and in distributing information, but the responsibility rests primarily with the individual, who should be definitely associated with at least one of the scientific organisations, not only to obtain the advantage of co-operation in the solution of problems, but to render whatever assistance possible to the solution of the difficulties of others. In this way scientific knowledge is more likely to be incorporated with production in meeting the present and future exigencies and in effecting progress.

Metallurgists to Visit America.

THE Institute of Metals and the Iron and Steel Institute have been invited by the American Institute of Mining and Metallurgical Engineers to hold their respective autumn meetings in New York in September, 1932; the meetings to be followed by a tour in U.S.A. and Canada, in the course of which many cities and industrial plants will be visited. This represents the first combined trip ever arranged by the two institutes, and according to the attractive programme the members who participate will have a very profitable time. Already, nearly 100 members have indicated their intention of travelling from a number of European starting-points. The trip, which will occupy about five weeks, is estimated to cost about £125, and in order to assist those who desire to participate, an arrangement has been made whereby payment can be made on an instalment plan. Full particulars of this plan, and the American visit generally, can be obtained from Mr. G. Shaw Scott, Secretary of the Institute of Metals, 36, Victoria Street, London, S.W. 1.

Forthcoming Meetings

INSTITUTION OF MECHANICAL ENGINEERS.

Mar. 20. General Meeting. Paper: "Modern Methods of Raising Water from Underground Sources, by R. S. Allen and W. E. W. Millington.

Mar. 23. Graduates' Section, London. Annual Meeting. Short papers for discussion.

Mar. 31. A Meeting of unusual interest will be held jointly by eleven Societies in the Hall of the Institution of Mechanical Engineers, Storey's Gate, St. James' Park, S.W. 1., by kind permission of the Council. Dr. S. J. Davies and Mr. E. Giffen, M.Sc., of King's College, Engineering Department will read a valuable paper entitled "Injection, Ignition and Combustion in High Speed, Heavy Oil Engines." The Chair will be taken by Mr. Loughnan Pendred, Past President of the Institution of Mechanical Engineers.

INSTITUTION OF MARINE ENGINEERS.

April 14. "The Caprotti-Bauer-Wach Marine Installation," by Mr. F. A. Pudney (of Messrs. Caprotti Valve Gears, Ltd.).

INSTITUTE OF METALS.

Mar. 17. Birmingham Section. "The Metallurgy of Some of the Rarer Metals," by C. J. Smithells, M.C., D.Sc.

April 9. London Section. Annual General Meeting.

April 17. Sheffield Section. "Extrusion," by R. Genders, M.B.E., M.Met.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Mar. 20. General Meeting. "Corrosion with Reference to Boilers." T. Millican.

April 17. General Meeting. "Corrosion of Oil Tankers." J. Foster King, C.B.E., Chief Surveyor, British Corporation Register of Shipping.

INSTITUTE OF BRITISH FOUNDRYMEN.

Mar. 27. Birmingham Branch. "The Melting of Cast Iron." T. G. Bamford, M.Sc.

April 15. Birmingham Branch. Works visit.

Mar. 28. East Midlands Branch. "Recent Developments in Special Cast Iron." A. B. Everest, Ph.D., B.Sc. London. (At Loughborough).

April 4. Lancashire Branch. I. Annual General Meeting. II. "Jobbing Moulding and Its Relation to the Engineer." S. Southcott, Briton Ferry.

Mar. 19. London Branch. "Some Practical Notes on Foundry Sands." J. L. Francis.

April 10. Middlesbrough Branch. I. Annual General Meeting. II. Cinematograph Film: "The Holley Permanent Mould" (by courtesy of The Foundry Plant and Machinery Co., Ltd., Glasgow). Described and explained by W. H. Bound, Middlesbrough.

Mar. 28. Newcastle Branch. "The Bracklesberg Process for Production of Grey Cast Iron."

Mar. 21. Scottish Branch. I. Annual General Meeting. II. Paper by Ronald Tullis.

Mar. 20. Sheffield Branch. "The Manufacture of High-class Marine Propellors," by Wesley Lambert, A.K.C., London.

April 17. Sheffield Branch. I. Annual General Meeting and Election of Officers. II. "The Use of Oil in Cupola Practice." J. R. Hyde, Stoke-on-Trent.

Mar. 28. Wales and Monmouth Branch. Annual General Meeting (at Cardiff).

ELECTROPLATERS' AND DEPOSITORS' TECHNICAL SOCIETY.

Mar. 18. "Some Investigations in Copper Deposition." A. W. Hotherstall, M.Sc.

April 15. "Experiments in Cadmium Plating." S. Wernick, M.Sc.

ROYAL AERONAUTICAL SOCIETY.

Mar. 19. "Research in the Berlin Technische Hochschule." Dr. W. Hoff.

April 16. "Aircraft Noise." Dr. A. H. Davis.

THE WOMEN'S ENGINEERING SOCIETY (INC.).

Mar. 18. "Power Transmission and the Modern Car." Miss Norah M. Jeans, M.W.E.S. (at the Lyceum Club, Piccadilly, London).

Correspondence.

The Canadian Building,
Trafalgar Square,
London, S.W. 1.

re CANADIAN PARTICIPATION IN THE BRITISH INDUSTRIES FAIR, BIRMINGHAM.

[The Editor, Metallurgia.]

Dear Sir,—The following paragraph of an article appearing on page 128 of your February issue of METALLURGIA has been drawn to my attention :—

> It is rather surprising that there should be a Canadian Section at the British Industries Fair, and it is open to question whether this is in strict keeping with the object of the Exhibition. There is no prejudice against Canada or any one of our colonies having trade exhibitions in this country, but the British Industries Fair is supposed to be representative ot goods made entirely in this country.

May I refer to the following quotation from the " General Regulations for Exhibitors " in the British Industries Fair ? :—

> All goods to be eligible for exhibition must have been manufactured or produced mainly within the British Empire.

For more detailed information in this connection I would refer you to the Organisers of this Fair, namely, the Department of Overseas Trade of His Majesty's Government, 35, Old Queen Street, London, S.W. 1.

In view of the above-quoted ruling, it is, to say the least, surprising that any publication in Great Britain should seriously take exception to Canada's participation in the British Industries Fair, more especially in consideration of the present endeavour, in all parts of the Empire, to foster a closer economic relationship within the Empire.

May I further draw your attention to the fact that, with the exception of the year 1925, Canada has exhibited in the British Industries Fair since 1923 ; for the first few years under the auspices of the Canadian Chamber of Commerce in Great Britain. Since 1927 the Canadian Sections both in London and Birmingham have been organised by the Canadian Government Exhibition Commission, Department of Trade and Commerce of Canada.

In view of these facts, is it not rather remarkable that your publication should express surprise at Canada's participation ?

Both the exhibitors in the Canadian Section, and the Exhibition Commission representing the Department of Trade and Commerce of the Canadian Government feel keenly that your comment is not only unfair, but will not conduce to a development of good feeling.

I trust that you will not regard it as unreasonable that I should request the publication of this letter of explanation in the next issue of your journal.—Yours truly,

G. W. RYASON.

The opinion expressed in our leader, to which the above letter refers, concerned manufactured articles, and was written with full knowledge ot the Regulations for Exhibitors. We are naturally desirous that the industrial depression under which this country is labouring should be overcome as rapidly as possible. While we recognise that the industry of the whole of the British Empire needs resuscitation, we have particular regard for our own national interests, and believe that this is the primary idea of the Fair. We reiterate that we have no prejudice against Canada or any other country within the British Commonwealth of Nations, but our manufacturers are called upon to bear very heavy burdens, and, in the present trade conditions, home industries have our first consideration.—EDITOR.

Symington Centenary.

The centenary of the death of William Symington, the father of marine engineering, occurs on Sunday, March 22 next. After a life of laborious effort, which included the first successful application of steam to navigation, the extension of which has been one of the greatest achievements of modern times, Symington suffered cruel misfortunes and died in London in almost complete poverty. He was buried at St. Botolph's Church, Aldgate, three days after his death on March 22, 1831. In 1903 the late Lord Bearsted (then Sir Marcus Samuel and Lord Mayor of London) unveiled a beautiful tablet which he himself had placed in the church to the memory of Symington.

On Sunday, March 22 next, at the request of the Institute of Marine Engineers and the Newcomen Society for the Study of the History of Engineering and Technology, the Rev. J. F. Marr, the vicar of St. Botolph's Church, Aldgate, E.C. 3, has kindly arranged to hold a memorial service at the Church at 11 a.m., when wreaths will be placed on the memorial, and an address will be delivered by Engineer-Vice-Admiral Sir Robert B. Dixon, K.C.B., D.Eng., late Engineer-in-Chief of the Royal Navy.

It is hoped that all branches of engineering, and particularly the leading public corporations, learned societies, and other bodies in any way connected with the maritime activities of the nation, to whom special invitations are being sent, will be represented at the ceremony.

The Council of the Institute of Marine Engineers trust that all members who possibly can will, by their presence, join in this centennial tribute to Symington, their pioneer predecessor.

Welding in Ship Construction.

The development of electric-arc welding since the war has been such that it is now considered possible to make use of it in the construction of ships ; great strides have already been made, and a large amount of preliminary research has been carried out in this respect.

In 1927 a 52-ft. all-welded boat was put into service by a German shipyard, and the results of this experiment proved very successful. The method employed in this case was " butt-welding," this being the system offering the greatest scope. Welding was adopted throughout, except for the upper and lower connections to deck, keel, and stern, which were riveted. For additional safety the butts of the shell-plating were so arranged that the butt was backed by a frame, both sides of which were attached to the shell-plating by light fillet welding ; also, bars were fitted inside the longitudinal weld seams. When completed the hull of this boat, which weighed 6 tons, was subjected to the test of being dropped from a height (9 ft. 10 in. forward and 13 ft. 1½ in. aft) into the water. The comparatively flat bottom not only survived this test, but it emerged from it without any indents or loosening of seams.

A comparison of the merits of a welded boat with those of a riveted boat, given in a paper by C. Wahl, translated by H. E. Johns, before the Institution of Engineers and Shipbuilders in Scotland, recently, reveals that the welded structure is more rigid and has less weight (the angle flanges and overlaps being saved), but without doubt is more expensive than the riveted structure. Soon after this launch had been taken into service, the builders received an order for two tank lighters of from 600 to 1,000 tons carrying capacity. After considerable discussion, it was decided that the same method and extent of welding should be adopted as with the experimental launch. The keel of the first vessel was laid on May 28, 1928, and she was launched four months later on September 4. Both lighters were subjected to the simple water-pressure test for tightness of joints. As in the case of the launch, it was found that no vibration existed while the Diesel engines were being tried, and this seems to confirm the fact that welded connections are firmer and more rigid than riveted connections. The two lighters have now been in service for two and one-and-a-half years respectively, and there have been no indications of the smallest leakage or defects.

The Bureau Veritas, the British Corporation, and Lloyd's Register of Shipping approved the adoption of electric welding in October, 1930. Although the approval only refers to a limited number of connections, it is a big step in progress, and it is to be hoped that welding will soon be introduced on a greater scale. There is no doubt that vessels may be built in a more profitable manner by adopting electric welding, and by the aid of more experienced designers and welders than hitherto.

The Institute of Metals

Twenty-third Annual General Meeting

The efforts of the Council to increase the usefulness of the Institute is admirably shown by the excellent attendance of members at the general meeting. All connected with non-ferrous metallurgy should definitely be associated with this organisation so that the results of scientific investigation may be disseminated and eventually consolidated in industry.

THE twenty-third annual general meeting of the Institute of Metals was held in London on March 11 and 12. At the business meeting the report of the Council for the year ended December 31, 1930, was presented by the Secretary, in which reference was made to the unprecedented disturbance in the economic life of the world during the year. In spite of this depression it is remarkable that the Institute has increased its membership, and the Treasurer's report reveals a satisfactory position.

These encouraging results have been brought about because there has been no relaxation of effort and no waning of interest in the work of the Institute on the part of the members. New ground has been broken in several directions—particularly as regards the publication of the abstracts section of the *Journal* in monthly, instead of half-yearly, parts—a publication that is admirably produced and gives very useful service. New activities have thus been added to those already in being, and these, in their turn, have been fully maintained. The Council feels that nothing could have justified the existence of the Institute more completely than that it has been able, in a time of such universal stress, thus to extend and increase the efficiency of its services to the science and practice of non-ferrous metallurgy—which services are of such outstanding international importance.

The election of officers for the year 1931 was announced at this meeting by the Secretary, and in the evening it was followed by a dinner and dance at the Trocadero Restaurant, Piccadilly Circus, W. 1, which functions were largely attended, not only by British members, but also by members from the Continent of Europe.

The meetings were well attended, and papers covering a wide range of subjects were presented. These were well received and caused much discussion; it is, however, only possible to summarise the papers here.

Scientific Work on Historical Objects.

Little scientific work by way of analysis and microscopic examination has been done on ancient Chinese manufactured bronze objects. Examination of a number of these bronze objects over a period of years, convinced Mr. William F. Collins that the copper-bearing compounds on them were in reality minerals rather than amorphous or cryptocrystalline chemical compounds, and his investigations are included in a paper on "The Corrosion of Early Chinese Bronzes." A series of objects classified by their art-forms and ranging from the earliest known periods of the Chinese bronze age, has been analysed and illustrated. The patina and patination deposits formed by their corrosion are stated to have resulted in formation of definite minerals. A list of minerals previously identified is given. Conditions leading to the formation of such minerals, based on analyses of the loess deposit in which Chinese bronzes are usually found, atmospheric conditions in China, and recent researches on corrosion of copper and bronze are discussed. The Chinese bronzes are found to contain an unusually high percentage of lead. This preliminary research is stated to indicate that the bronze metallurgy of the early Chinese is distinct from that of the Sumerians. The paper includes a list showing the analyses of a considerable number of Chinese bronzes, collected from different sources.

Another historical subject formed the basis of an investigation by Dr. C. F. Elam on the "Microstructures of Fifteen Silver Greek Coins (500–300 B.C.) and Some Forgeries." The paper deals with the microstructure of a number of genuine ancient silver Greek coins, together with that of some forgeries. The investigation showed that the structure varied considerably, although coins from the same mint and period resembled each other. All the genuine coins showed evidence of having been struck between dies as opposed to the forgeries, which, with one exception, were made by casting only. Analyses indicated that the coins were sometimes made from almost pure silver, and sometimes copper was added. The forgeries contained copper, and in two cases zinc.

Deformation of a Single Crystal of Silver.

During a series of investigations on the behaviour of single crystals of zinc and antimony under alternating torsional stress, by a number of workers, information was obtained in regard to the mode of formation of mechanical twins. The results of the work on zinc apparently indicated that the formation of twins depended to a large extent on the slip system, and the actual planes on which twins were formed at any point were found to depend simply on the direction of slip at that point. The information obtained appeared to be of considerable interest, and it was thought that the work could profitably be extended to include a study of the formation of mechanical twins in materials for which the slip system was of more complicated nature. Silver and copper, both of which conform to the face-centred cubic lattice system, appeared to be suitable, as it was known that in the polycrystalline state both materials twinned very readily. Accordingly, it was decided to test a single crystal of silver with the special object of studying the formation of twins in relation to the applied stresses and to the resulting slip system.

The results of this work were presented in a paper by Messrs. H. J. Gough and H. L. Cox. Throughout the tests, however, no definite twin markings were observed, although the surface of the specimen was covered by a complete system of slip-bands in good agreement with the maximum resolved shear-stress law. After the specimen had been fractured in torsional fatigue, the test portion of the specimen (containing the crack) was annealed in vacuum with the object of revealing the presence of twins. No sign of twinning was, however, observed. After the completion of the torsional test, compression specimens were machined out of the enlarged ends of the torsion specimen. These specimens were compressed by static and impulsive forces, the maximum strain imposed being about 5%. Again, no twin markings were observed, although in every case profuse slip on the most highly stressed octahedral planes was produced.

The choice of silver as a suitable material for the study of the formation of twin bands under applied stress was made on the grounds that in the aggregate form silver is known to twin very readily. The complete failure to produce twins in the present experiments is, therefore, somewhat surprising; nevertheless, this failure must be held to constitute a very important result as betraying an essential difference between the single crystal and the aggregate.

Equilibrium Diagrams.

The investigation described in a paper on "The Constitution of the Cadmium-rich Alloys of the System Cadmium Silver," by Dr. P. J. Durrant, was undertaken

in order to modify or confirm the equilibrium diagram obtained by Petrenko and Federow after an exhaustive study of the system cadmium-silver, now usually accepted. The need has arisen as a result of more recent investigations by Natta and Freri, and Astrand and Westgren. In these investigations the crystalline structure of the silver-cadmium alloys was determined by X-ray analysis, and the results were in disagreement with the equilibrium diagram by Petrenko and Federow.

The reinvestigations covered by this paper were by the methods of thermal and micrographic analysis; the constitution of the alloys of cadmium and silver being from 0 to 40% by weight of silver. The liquidus has been found to consist of four smooth curves, which intersect with peritectic horizontals at 343°, 592°, and 640° C. In the solid state the system gives rise to the following solid solutions: "I" extending from 0 to 6% by weight of silver: "II" extending from 18 to 33·5% by weight of silver; "III" extending from 36·2 to 39% by weight of silver. The solid solution "II" includes the two solid solutions which Petrenko and Federow described as ϵ and δ. The solidus and liquidus of alloys of phase "II" are roughly parallel, and do not intersect, as was previously thought, at 25 atoms per cent. of silver. No transformations below the solidus have been detected in any of the solid solutions, but the examination of solid solution "III" has not been carried out below 400°C.

The copper-silver alloys have been studied by many investigators, but the equilibrium diagram generally accepted as correct is that of Lepkowski, who shows that, at the eutectic temperature, silver can hold only 6% of copper and copper only 2% of silver in solid solution. During recent years much research into the behaviour and properties of the silver-rich alloys has caused a growing dissatisfaction with the diagram, with the result that the system has attracted further attention and reinvestigation. This paper contains a description of work on the subject by Dr. D. Stockdale, and the resulting diagram obtained differs in many respects from that usually found in the text-books, but it is in close agreement with two diagrams which have been published recently in Germany. The behaviour of standard silver, when it is annealed, is in conformity with the constitution of the alloys as it is now described. The paper ends with a short summary of the results of other workers, and a bibliography is appended.

The equilibrium diagram of the silver-rich aluminium-silver alloys was investigated by Petrenko in 1905, who used the method of thermal analysis only. The investigation which forms the basis of this paper has been carried out with aluminium of 99·95% purity, which was not available to Petrenko, and the results have been extended by micrographic analysis. Unfortunately, the time at the disposal of Messrs. T. P. Hoar and R. K. Rowntree, who conducted the investigation, was short, and the work is consequently incomplete, but the results are of considerable interest. A description of the investigation is included in a paper together with the modified diagram constructed from points found by cooling curves. In general form the liquidus curve is in agreement with that constructed by Petrenko, but the freezing points are all from 5°—10° C. higher than those of Petrenko's corresponding alloys. There are two breaks in the curve, the first at 6·2% aluminium, 779° C., the second at 10·8% aluminium, 729° C., no maxima or minima occur. Attempts to fix the solidus by quenching yielded negative results with the exception of a point in the γ solidus region. The position of this suggests that the boundary is vertical, or nearly so, as in the aluminium-copper system. The solidus curve has been entered on the diagram as a dotted line, indicating its approximate location only.

Influence of Pressure and Temperature on the Extrusion of Metals.

The experiments described in this paper refer to the extrusion phenomena of the metals—lead, cadmium, bismuth, and tin. The mechanism of the flow of metal during extrusion by the direct and inverted methods have been studied by Messrs. C. E. Pearson and Dr. J. A. Smythe. In the former method pressure is applied by means of a ram to a billet of metal lying in a strong cylindrical container, in order to cause a rod, or other section, to be extruded through a die fixed at the other end of the container. In the inverted method the container is closed at one end and the die is placed between the billet and the ram, so that as the ram is advanced the die is pressed into the billet, causing the extrusion of the rod through the die. These different arrangements have an important effect on the conduct of the process and the flow of the metal. In direct extrusion the billet has to move forward relatively to the wall of the container, with which it is in contact, and, as a result of the friction between the two the billet is sheared through the outer portion. Genders has shown that the advancing ram, or pad placed between ram and billet, turns in this outer portion, so that it moves towards the centre of the rear end of the billet and is carried with the more rapidly moving central part into the die, where it frequently gives rise to a defect which may extend over 30% or more of the extruded rod, due to the inclusion of dirt and oxide from the skin of the billet. The inverted process, on the other hand, involves no relative motion between the billet and the container, so that shearing of the billet is avoided. As the die moves forward, the metal immediately in front of it flows through the die aperture, and the metal of the billet is disturbed only near the die.

The work on this subject by other investigators has been confirmed and extended. The chief part of the present work, however, is concerned with the determination, under precise control, of the relationship between the rate of extrusion, pressure, and temperature. This relationship is expressed in a series of curves, the mathematical treatment of which is included in the paper.

Some Properties of Metallic Cadmium.

Investigations into the properties of cadmium and its alloys have been in progress in the Metallurgical Department of the National Physical Laboratory during the last few years. Those that have been published relate to studies of the constitution and physical properties of the binary and ternary alloys of cadmium with zinc and copper. The present investigation, a report of which was presented by Dr. C. H. M. Jenkins, deals with the properties of the metal itself, and some of the results will be of general interest in the further study of the "softer" metals. The object of this latter research has been two-fold—viz., to examine the property of the metal, and to consider evidence, if any, of a polymorphic change in the material. Particular attention has been paid to the physical properties of the pure metal prepared in various manners, the effect of heat-treatment and ageing at room temperatures, and the behaviour of the material as indicated by microscopic examination.

The physical properties of cadmium were investigated by means of tensile, ball-hardness tests, and electrical resistivity measurements on "aged" and heat-treated material in the cast, forged, and rolled conditions. The research indicated that hardness changes in rolled material which occur at room temperature are markedly affected by slight changes in the conditions of working, such as the temperature produced during rolling, or whether rod or sheet is the subject of examination. At the commencement of cold-working, the metal hardens, but a continuance causes softening. After the completion of the process the material hardens spontaneously, attaining a maximum value, as determined by a ball test, after ageing for about one hour. By maintaining cadmium cold during rolling, the material produced possesses a high strength in the initial stages of a tensile test, but is markedly softer as soon as extension commences. In the short-time tensile tests, as usually made, worked material is found to be stronger than cast, but cast cadmium appears to be stronger than either rolled or forged material in long-time ball hardness

tests (time penetration). This phenomenon is confirmed at room temperature by comparative prolonged stress tests in which the rate of steady flow under load for an aged rolled specimen is probably fifty times as great as that of a cast specimen.

Some of the changes noticed are possibly observable in other metals, especially if they recrystallise approximately at room temperature. In the present instance it appears that the recrystallisation temperature is progressively lower according to the degree of previous working and the extent of ageing. In general, the behaviour is not dissimilar to that of metals such as iron, in the range of temperature in which recrystallisation readily occurs. The preparation of suitable specimens for microscopic examination was undertaken in such a manner that partial chemical solution of the surface takes place during polishing. The susceptibility of this metal to recrystallisation and strain effects, as the result of polishing the surface of the specimen, was amply confirmed by microscopic investigation. The material in the cold-rolled condition is found to be completely recrystallised. Ageing at room temperature results in appreciable grain growth after a long period of time, such as five years, which is not evident on examination after ageing for several months.

Some of the changes in properties, such as density variations, have caused other investigators to suggest that a feebly marked transformation exists in crystalline aggregates of cadmium.

The present work shows that no marked allotropic change occurs in the material. It is possible that under certain temperature and pressure conditions an allotropic modification can be found, and for investigations on these lines single crystals of cadmium may prove to be a subject of more fruitful examination than the aggregates now consider.

In connection with this work an X-ray investigation of cadmium rolled hot and cold was undertaken by Mr. G. D. Preston, and his results form an appendix to this paper. This additional work was undertaken primarily with a view to ascertain whether the marked differences in mechanical behaviour of the metal in the two conditions could be ascribed to any allotropic change in the material. The results of this investigation show that the X-ray examination of hot- and of cold-rolled cadmium does not indicate any difference in the material such as would be brought about by allotropic modification. There are, however, marked differences in the properties of the material which are caused by the occurrence of a preferred orientation.

Dimensional Stability of Heat-treated Aluminium Alloys.

The systematic study of aluminium and its alloys, which has long been carried on in the Metallurgy Department of the National Physical Laboratory, has been continued by an investigation carried out under the direction of the Alloys Sub-Committee of the Aeronautical Research Committee of the Department of Scientific and Industrial Research. The work was undertaken to investigate a report that serious secular changes occur in light alloys during storage. The results of this work were presented in the first part of a paper by Messrs. J. D. Grogan and D. Clayton. The alloys considered were cast and wrought "Y" alloy, wrought duralumin and chill and sand-cast "2 L 5" alloy, but, as the secular changes, which occur after the normal ageing process is substantially complete, were found to be small enough to be ignored in normal engineering practice, as far as the alloys examined during the course of this investigation were concerned, it was considered sufficient to present this part of the investigation in outline only.

The second part of this paper refers to an investigation which was carried out to determine the magnitude of the changes which occur when heat-treated light alloys are machined. The alloys examined were: Copper-silicon, 25 S-alloy, Y-alloy, and duralumin, and the method employed was a modification of that described by Heyn in the May (1914) lecture to this Institute. Concentric rings were machined from the central portion of a heat-treated cylinder, so that the test-piece assumed the form of a dumb-bell. Measurements of the length were made both at the centre and at the periphery.

The investigation of these commercial heat-treated aluminium alloys, subsequent to the completion of the normal ageing process, indicated that serious dimensional changes occur when machining operations are carried out on material quenched in cold water. These changes are reduced to relatively small proportions in "Y" alloy and duralumin, the only alloys examined in this way, by the employment of boiling water as quenching medium. Cold cotton-seed oil produces intermediate effects. These alloys, when quenched in boiling water, develop satisfactory mechanical properties.

Deformation of Aluminium under Prolonged Loading.

During recent years the demand for materials strong at high temperatures has led to numerous studies of the properties of materials when hot. Such investigations have mainly aimed at determining the strength or rate of flow of metals which have been shown to "creep" under prolonged loading and fail at stresses much less than those necessary to break them in a short time. But while data have been accumulated on the mechanical behaviour of metals, practically nothing is as yet known of the mechanism of flow and fracture under "creep" conditions. Experiments described in a paper presented by Dr. D. Hanson and Mr. A. Wheeler have been undertaken with a view to studying this mechanism principally by metallographic methods similar to those that have been so successful in explaining flow and fracture under static and varying stresses at room temperature. Owing to the difficulty of examining the changes in microstructure of metallic specimens of most of the engineering materials used at high temperatures, the authors have conducted their experiments on metals which exhibit the phenomena of creep at lower temperatures; most of their work has been done with aluminium, which will retain a metallographic polish after exposure to high temperatures, but experiments have also been performed with zinc and lead. These three metals possess the added advantage that test-pieces consisting of one crystal only can be made from them without great difficulty. The paper describes only experiments on aluminium.

The principal method used has consisted in examining the changes in microstructure of polished specimens subjected to static stresses at room and elevated temperatures. Aluminium was chosen principally because it exhibits the phenomena of "creep" at moderate temperatures, at which a polished surface capable of revealing the microstructural features of deformation can easily be preserved. A further advantage of this metal is that the mechanism of its deformation under many other types of stressing has already been studied. Specimens consisting of ordinary aggregates of crystals, of crystals of widely differing size, and of single crystals have been used. Measurements of the densities of the broken test-pieces have also been made.

As a result of this investigation, the authors conclude that the extension under a prolonged load that will ultimately break the metal may be conveniently considered as consisting of three periods: (*a*) A period of primary extension, during which the rate of flow diminishes; (*b*) a period during which the flow is very slow or even suspended: (*c*) a period during which the extension again continuously increases until fracture occurs.

During the first period the flow of the metal is the result of slip within the crystals, and flow diminishes owing to the hardening effect of slip.

The behaviour during the second and third periods varies with different specimens.

Three types of failure have been recognised under

creep conditions: (*a*) Failure by intercrystalline cracking; cracks form while the elongation is low, and the metal fails with little reduction of area at the fracture; (*b*) failure by the resumption of slipping within the original crystals, leading to a fracture of the normal tensile type; (*c*) failure through the recrystallisation of the metal, removing strain-hardening and permitting further flow of the softened metal: the metal pulls out to a point fracture, with a high elongation.

Aluminium can fail by "creep" at room temperature.

Aluminium consisting of uniform aggregates of crystals fails at 250° C. by inter-crystalline cracking.

Aluminium aggregates at room temperature, and aluminium single crystal specimens at all temperatures, fail under creep conditions by shear along the slip planes.

In single crystals, when flow recommences, slip occurs only on some of the surfaces that had previously slipped during the primary flow.

The prolonged action of a suitable stress can cause disintegration of a metal either at the junctions of the grains or on surfaces of previous slip, and failure—*i.e.*, fracture—must be regarded as having commenced when this weakening occurs.

Under suitable conditions—*e.g.*, in crystal aggregates with moderate rates of flow at 250° C., or with very slow rates of flow in single crystals—slip is distributed over a very large number of slip surfaces, and a polished surface of the metal may show little or no signs of slip bands.

No change in density is believed to occur when a crystal is distorted by moderate amounts; changes in density in the case of crystal aggregates are thought to occur at grain boundaries.

The view is expressed that rupture of the crystals commences along slip planes formed at an early stage in the deformation of the metal.

The results are consistent with the theory of slip and rupture previously advanced by Gough, Hanson, and Wright.

The Resistance of Treated Super-Duralumin.

The effect of artificial ageing upon the resistance of super-duralumin to corrosion by sea-water has been investigated by Dr. K. L. Meissner, and the work accomplished forms the basis of a paper. The author investigated the resistance to corrosion of Lautal and duralumin as a function of the ageing treatment some years ago. On that occasion an abbreviated corrosion test was used, based only on the determination of the loss in weight, and such a method can be reliable only if the sample is uniformly attacked or dissolved by the corroding medium. If the corrosion is of another kind, determination by loss of weight is not sufficient to give an accurate result for resistance to corrosion, especially if intercrystalline corrosion is taking place. On this present investigation, the first part of which was published in the *Journal of the Institute of Metals* in 1930, the author, instead of using a synthetic solution, carried out his tests in the North Sea, and the degree of corrosion in the test strips was determined by the following methods: (1) The appearance of the surface; (2) the loss in weight; (3) the reduction in tensile properties, including yield-point, tensile strength, and elongation; (4) the microscopic examination of the kind of corrosion.

The test strips of super-duralumin (duralumin containing 0·8% silicon) were 2 mm. thick, and the tests were carried out between high and low water marks for a period of three months. The strips were previously annealed for 20 mins. at 500° C., quenched in cold water, aged at least five days at room temperature, and tempered for 20 to 40 hours from 50° to 200° C. A different "pock-form corrosion" combined with highly deleterious effect on the tensile properties, and primarily caused by intercrystalline corrosion, was found in an intermediate range of temperature at 125°–145° C., and especially at 140° C. Strips which were artificially aged at lower or at higher temperatures, although also attacked by intercrystalline corrosion, showed no pocks, but still had a relatively smooth surface.

The Effects of Impurities on Copper.

Research work on the effect of impurities on copper, for the British Non-Ferrous Metals Research Association, has been in progress for some considerable time at the National Physical Laboratory under the general direction of Dr. Rosenhain. The investigations of the separate and individual effects of a number of impurities have been completed, and one of the papers presented at the meeting dealing with the effect of antimony gave results of the final work in this series. Further research work on the subject is devoted to the combined effect of two or more impurities. Of these the combined effect of antimony and arsenic has been studied, and the work involved, together with the results obtained, form the basis of a second paper. These papers were presented by Messrs. S. L. Archbutt and W. E. Prytherch.

The effect of varying quantities of antimony and arsenic on copper has occupied the attention of a number of workers, and published work relating to the subject is reviewed. The present investigation, on the effect of antimony on the properties of copper relates to quantities up to 0·85%, in which other impurities and oxygen have been kept as low as practicable. The oxygen content, for instance, has been kept below 0·02%. The results of this investigation are given under the following heads:—

(*a*) Preparation and casting; (*b*) hot and cold rolling; (*c*) density; (*d*) tensile tests; (*e*) notched-bar (Izod) impact tests; (*f*) Wöhler fatigue range; (*g*) softening temperatures and Brinell hardness; (*h*) electrical conductivity; (*i*) solubility of aluminium in solid copper; and (*j*) macro- and micro-structure. The conclusions arrived at as a result of this investigation may be summarised as follows:—

Alloys of copper with small percentages of antimony and low in oxygen content can be satisfactorily prepared by melting the copper in vacuo in a high-frequency induction furnace. Superior soundness and control of composition in cast billets can be obtained by this method as compared with melting in a gas-fired crucible furnace, especially where small quantities are concerned. It must be borne in mind, however, particularly in comparing the mechanical properties and the composition with those of the arsenic-copper series, that the presence of oxygen, in amounts such as are usual in technical copper, exerts a very marked effect. Alloys containing up to 0·47% of antimony can be hot-rolled satisfactorily, and the annealed hot-rolled rod satisfactorily withstands further cold reduction. An alloy containing 0·85% of antimony was hot-short.

Cold rolling from annealed cast billets to $\frac{5}{8}$ in. diameter rod presents no difficulty up to 0·85% of antimony, provided that the billets are reasonably sound. In three alloys containing 0·043, 0·22, and 0·47% of antimony respectively, this cold-rolled rod withstood flattening cold under the power hammer and further cold-rolling to strip 0·05 in. thick. Densities of cast billets may be variable. Regular values are generally obtained for rolled rod, approximating to 8·92, up to the highest antimony content rolled, 0·85%.

Tensile strength at room temperature of hot/cold-rolled and of cold-rolled rod is improved by the addition of antimony, in the former case up to 0·22%, and in the latter up to the highest content rolled, 0·85%, without pronounced effect on ductility. The alloys appear, therefore, to withstand severe cold-working without over-rolling effects. The effect of the presence of quite small amounts of antimony—*e.g.*, up to 0·05%, on tensile strength, is remarkable. In annealed rod, tensile strength increases up to 0·22% of antimony without loss of ductility, a tensile strength of 14·9 tons per sq. in. being reached with 67% extension. At 250° C. tensile strength is improved up to 0·22% of antimony. With this composition an ultimate stress of 11·7 tons per sq. in. with 52% extension is obtained

in annealed rod. Small amounts of antimony appear at least as effective as arsenic in strengthening copper at 250° C., and greater amounts up to 0·22% are even more effective. In hot/cold-rolled rod under all three conditions referred to above some impairment of tensile properties is found beyond 0·22% of antimony, which, however, is not reflected in the fatigue tests.

The fatigue properties of copper are improved by the addition of antimony up to the highest content, 0·47%, hot-rolled. With this composition a safe range of stress of ± 7·8 tons per sq. in. was obtained, as compared with ± 5 to ± 6 tons per sq. in., typical of high-purity copper. Antimony does not appear to have any pronounced effect on the toughness of copper. In annealed rod up to 0·47% of antimony, the Izod test-pieces all bent with only a small crack, and showed fine-grained fractures. Complete fractures were not obtained even in severely cold-worked rod. The softening temperature of cold-worked copper is raised by antimony; its effect in this respect being more pronounced than that of arsenic. Antimony lowers the electrical conductivity of copper very considerably, but is only approximately half as deleterious in this respect as arsenic.

Combined Effect of Antimony and Arsenic.

The second paper, by the same authors, on combined effect of antimony and arsenic in copper, gives a description and results of an investigation. Similar precautions were taken in keeping impurities low, and the results are given under similar headings, with the addition that a comparison is made of arsenic-copper, antimony-copper, and antimony-arsenic-copper alloys low in oxygen. As with the antimony-copper alloys, the antimony-arsenic-copper alloys can be satisfactorily prepared in a high-frequency induction furnace. Billets of good density and surface are obtained by pouring into cast-iron moulds dressed with lamp-black and pre-heated to 100° C.

Within the limits of composition studied, arsenic-antimony-copper alloys can be hot-rolled without difficulty, so that it appears that arsenic assists the hot-rolling of antimony-copper alloys. Annealed cast billet can be cold-rolled to ⅝ in. diameter rod, and this rod will withstand flattening cold and further cold-rolling to thin strip. Antimony improves the tensile strength of arsenical copper over the range of arsenic contents studied (0·05—0·50%), particularly in annealed rod, both at room temperature and at 250° C. Apart from some irregularities, the added strength is usually accompanied by superior ductility. In general, the improvement in strength increases with increasing antimony content. Thus, at 250° C. a tensile strength of more than 13 tons per sq. in. is reached in annealed rod containing arsenic 0·059 and antimony 0·49%, and at room temperature 15·6 tons per sq. in., with 60% extension.

The alloys withstand severe cold-rolling from annealed cast billet without over-rolling effects. With antimony 0·50 and arsenic 0·53% a tensile strength of 29·6 tons per sq. in., with 10·4% extension, was obtained from cold-rolled rod, and 37·2 tons per sq. in., with 2·3% extension on further cold-rolling to strip 0·05 in. thick. The fatigue properties of these alloys show considerable improvement over those of arsenic-copper. The fatigue range increases with increase of antimony content. The alloy containing arsenic 0·5 and antimony 0·5% has a fatigue range, in the Wöhler test, of 7·8 tons per sq. in., on a basis of 20 million reversals. The notched-bar toughness appears satisfactory.

Except in material cold-rolled from cast billet, the results of mechanical tests are little affected by increasing arsenic content over the range studied, and appear to depend chiefly on the intrinsic properties of the corresponding binary antimony-copper alloy. Generally, the effect of antimony appears similar to, but more pronounced than, that of arsenic, but arsenic and antimony in conjunction lead to superior properties, particularly at high temperatures and in annealed material.

Antimony and arsenic together appear to raise the softening temperature of copper containing less than 0·02% of oxygen to a greater extent than does arsenic alone.

The Effect of Silicon on the Hardness of Aluminium-Copper Alloys.

The effect of silicon on the Brinell hardness, mechanical properties, and microstructure of three groups of aluminium-copper alloys containing 5·0, 7·25, and 10·0% aluminium respectively, has been investigated, and a paper describing the results of the study was presented by Mr. L. J. Brice. Briefly, the results show that the general properties of the 5·0% aluminium group are improved with addition of silicon up to 2·0%; further addition of silicon gives progressively increased hardness, but leads to reduced toughness and ductility, although considerable improvements can be effected by heat-treatment. An annealed alloy containing 3·5% silicon has properties (yield-point, 15 tons per sq. in.; maximum stress, 35 tons per sq. in.; elongation, 33% on 1·265 in.; Izod impact figure, 30 ft.-lb.; Brinell hardness, 132) comparable with those of a normal 10% "aluminium bronze." Although greatly reduced, the ductility of the heat-treated alloys is not destroyed by the addition of up to 4·5% silicon.

With 7·25% aluminium, the addition of up to 4·0% silicon gives progressively increased yield-point and maximum stress and hardness, with decreased ductility and toughness. Good combination of properties is obtained with 1·0% silicon, whilst with 2·86% silicon the following can be obtained: Yield-point, 20·0 tons per sq. in.; maximum stress, 41·8 tons per sq. in.; elongation, 12·8% on 1·265 in.; Izod impact figure, 16 ft.-lb.; Brinell hardness, 196. The forged alloy containing 1·88% silicon gives: Yield-point, 26·5 tons per sq. in.; maximum stress, 44·2 tons per sq. in.; elongation, 25% on 1·265 in.; Izod impact figure, 24 ft.-lb.; Brinell hardness, 186. With more than 3·0% silicon, the ductility and toughness of the alloys in all conditions are so low as to render them useless for practical purposes.

In the 10·0% aluminium alloys the addition of 1·0% silicon gives a greatly increased hardness, but the ductility and toughness are extremely low. Higher percentages of silicon render the alloys mechanically useless.

In all alloys, changes of mechanical properties are associated with marked changes in microstructure.

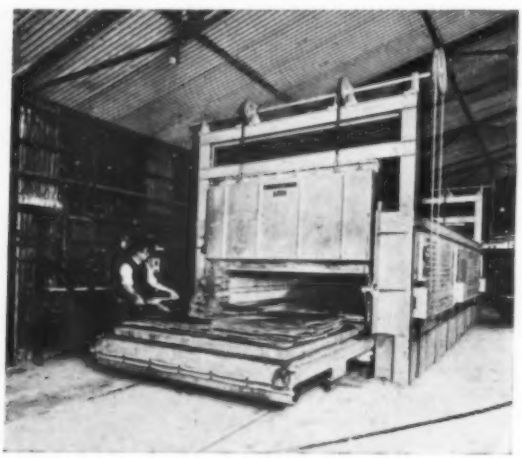
Rolling High-phosphor Copper Alloys.

In view of the fact that alloys of copper and phosphorus containing up to as much as 5% of phosphorus are being marketed at the present time in the form of more or less ductile strip, it is interesting to note that Mr. Owen W. Ellis, who developed a method whereby the manufacture of such strip could be accomplished, gave details of the process in the form of a paper. The problem in regard to these high phosphor alloys for the production of ductile strip for use as a high melting point solder, mainly in the electrical industry, was submitted by the author, who is a director of metallurgical research, Ontario Research Foundation, Toronto.

The rolling experiments involved are described in this paper and include alloys of copper with from 2 to 6% phosphorus, with and without the addition of 5, 10, or 15% manganese or nickel. The results indicate that the plain phosphorus-copper alloys can all be successfully hot-rolled at 450°—650° C. to produce strip 0·021 in. thick, provided that only small reductions of thickness are made at each stage of rolling. In this way the copper-copper phosphide eutectic structure is thoroughly broken up and the strip can then be cold-rolled to 0·015 in. Strip, 0·018 in. thick and 1·2 in. wide, made by hot-rolling the 5% phosphorus alloy at 450° C. has a tensile strength of 88,000 lb. per sq. in., and is suitable for use as a high melting point solder for the electrical industry. Addition of manganese or nickel to the alloy renders it harder and much more brittle in the hot-rolling process.

Electric Annealing of Aluminium.

THE growth in the industrial uses of aluminium during recent years has been very marked, and considerable progress has been made by the producers of the metal and its alloys to ensure a very high-grade product of known physical characteristics. One of the largest and most important works in this country devoted to this purpose is that of the Aluminium Corporation, Ltd. In addition to the extensive plant required for the production of aluminium in ingot and bar form, these works have an extensive and well-equipped rolling mill for the manufacture of every kind of sheet product. This Corporation is thus in a position to supply its product to each industry in the form most suitable for the particular purpose to which it is to be applied. To enable this to be done, it has been necessary to maintain the works at the highest standard of efficiency by the installation of modern equipment in every department. In order to facilitate the very precise annealing of aluminium sheets on a large scale, a large, single-track multi-car type electric annealing furnace has recently been installed, which has an effective hearth area 24 ft. long by 7 ft. 5 in. wide. This furnace has an electric loading of 150 kw., the heating elements being arranged to ensure phasal balance on a 440-volt, 3-phase, 50-cycle supply.



View from Loading End of Furnace.

The correct disposition of heating elements in a furnace of this size is of primary importance. Composed of high-grade nickel-chromium alloy, the elements are placed on the side walls in each section of the car hearth, and also suspended from the roof. Those in the car hearth each constitute a self-contained and independent unit or circuit, and an interesting feature of design is the substitution of running contacts for the trailing cables usually employed. This eliminates the danger and inconvenience which are invariably associated with trailing cables in such circumstances. The running contacts are situated below the cars, and are therefore virtually outside the furnace proper, and not subjected to the heat of the furnace. The roof elements are suspended by a patented method, which ensures long life by relieving the elements of all strain and stress due to expansion and contraction. The furnace, which is of the G.E.C. magnet type, is controlled automatically by gear supplied by The Cambridge Instrument Co., Ltd., and works in conjunction with G.E.C. Witton contactors. Fitted with this automatic control gear the furnace is operated at a temperature within five degrees of any setting of the instrument. An electrically driven time switch is capable of bringing the furnace to temperature in time for work to commence on Monday morning, the furnace being closed down for the week-end.

The doors at each end of the furnace are of the suspended counterweighted type, well insulated, and sand-sealed both at the top and bottom. Special switches are provided which automatically switch off the current from the car hearth when the doors are raised, and similarly switch on when they are closed.

The equipment comprises six cars or trolleys, on which the aluminium sheets are piled. There are four cars in the furnace at one time, and the two others are provided to facilitate cooling, loading, and unloading. These cars are effectively sand-sealed along both sides and at the furnace ends, and there is also an adequate seal between the ends of the adjoining cars. As each car is unloaded it is returned to the charging end along a rail track running parallel with the furnace.

It is of interest to note that this new furnace occupies the site of an older type of electric furnace which it has superseded, and is turning out a product of exceptional regularity and quality.

New Electric Power-station.

THE Leeds Corporation Electricity Department's new power-station at Kirkstall, which was put into operation last October, has already proved its efficiency in several directions, although it is not yet fully completed. It is admirably situated, with every facility for both canal and railway transport, while the River Aire provides an ample supply of water for condensing purposes. The actual buildings consist of an administrative block, boiler-house, engine-house, control-room, and switch-house. An interesting feature of the works is the use of pulverised-fuel firing for the three Stirling patent high-duty tri-drum boilers. Coal is delivered by barges direct from the colliery to a large dock, where it is lifted out and discharged into a 300-ton raw-coal bunker; it is then transported on belt conveyers to the dryer-house, where it is dried at the rate of about 12 tons per hour by Ruggles-Coles A 12-type dryers, and then conveyed to the pulveriser-house. The pulverisers are of the "Raymond" type, each able to pulverise some 15 tons of dry coal per hour to such a fine state that 86% of the product will pass through a 100-mesh screen. After the pulverising process the fuel is transported by pneumatic pumps to 60-ton bunkers in the boiler-house. The firing arrangements for the Stirling boilers consist of three burners of the turbulent type, served by duplex feeders, and housed in "Lopulco"-type combustion chambers; these consist of water-cooled rear and side walls of Murray fine tube construction. Each boiler is equipped with an M.L.S. multiple-hoop, single-pass superheater, having an effective heating surface of 2,950 sq. ft., and a Foster economiser with heating surface of 6,480 sq. ft., while Ljungström preheaters are also fitted. The air necessary for combustion is provided by air fans of the usual "Sirocco" construction. The International Combustion, Ltd., of London, are responsible for the coal-preparation plant, and for the equipment of the boiler-house.

The generator-house, of which a third is now completed, contains two units, installed by the British Thomson-Houston Co., Ltd., of Rugby, each having a maximum continuous output of 25,000 kw., and consisting of a two-cylinder turbine, the cast-steel high-pressure cylinder being of the pure impulse type with 16 stages, whilst the cast-iron low-pressure cylinder is of the double-flow type fitted with reaction blading throughout. The rotor shaft and core are made from a solid forging of mild alloy steel. The vertical regenerative condensers are specially designed to fulfil the conditions imposed by the use of the River Aire for cooling purposes, and their centrifugal water-circulating system is controlled by two pumps, each having a capacity of 2,400,000 gals. per hour. The feed-heating plant has three stages, and is designed to give an ultimate temperature of 300° F. Situated along one side of the engine-room is the main control room, which is large enough to accommodate all panels that may be required when the generating station is fully extended; that is to say, when the Central Electricity Board install the control apparatus for the sub-station which is being constructed alongside the power-station. At this sub-station, electrical energy generated at Kirkstall will be transformed for distribution over the National grid system. The building housing the main switchgear contains, on one side, the main alternator switches and the "grid" system connections, and on the other side the four main transformer units which connect to Whitehall Road. All the swtichgear, which is of the metal-clad type with vertical isolation, has been provided by Messrs. Ferguson, Pailin, Ltd., of Manchester.

Kirkstall Power-station has been classed by the Board as a "Selected Station."

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part VI.—Ingot Moulds.

The various types of moulds used in casting aluminium rolling ingots are discussed in this article.

AS has been pointed out by Newman,[7] in discussing the casting of cupreous-alloy ingots for rolling, the function of the ingot mould is to contain the metal and to conduct the heat away so that it will freeze in a reasonable period of time. These elementary requirements are, of course, fulfilled in practically any type of chill mould. It is obvious, however, that a given type of mould may serve adequately as a container for metal and as a conductor of heat, but, at the same time, be a highly unsatisfactory appliance for the production of rolling ingots. Leaving out of consideration the effect of the type of mould and its design on the structure and quality of the ingots, it is at least essential that the mould be practical. This means that the initial cost must be reasonable, maintenance low, life satisfactory, and operation rapid. Moreover, a good mould set-up should be easily operative by any intelligent unskilled labour.

Unfortunately, comparatively little is known, based on scientific investigations, regarding the effects of different mould types or alterations in design on the quality of aluminium rolling ingots. There is plenty of opinion regarding these matters, based on practical experience, but the opinion of one operator is often found to be diametrically opposed to that of another.

The conventional mould used in the majority of mills is that known as the tilting, vertical book type—so-called because the long axis of the ingot is in a vertical position when pouring is completed, the mould is tilted down from an approximately horizontal to a vertical position as pouring proceeds, and the separable halves of the mould are moved together or apart by swinging on a hinge, like the leaves of a book. Some mill men avoid the problems involved in the operation of tilting vertical book moulds by pouring their ingots in flat (horizontal), open, stationary moulds. It is highly doubtful that good rolling ingots can be produced in this latter type of mould, even if the top (shrinkage) surface is scalped.

Although indubitably there are better methods of producing aluminium rolling ingots than by pouring in tilting book moulds, so far these have not been adopted to any extent in practice. At the present time the total tonnage of ingots poured, for rolling into market sheet, in moulds other than the book type, is relatively small. More or less improvement has come of late years in methods of mounting the tilting, vertical book moulds and in the adaptation of standard mechanical devices for raising and lowering. However, the general features of mould design proper have remained more or less the same.

In the present article the various types of ingot moulds which have found application are discussed, stress being laid on the tilting, vertical book type. Some information is given on the design of moulds. Mechanism for operating tilting moulds and mould mountings and fittings are dealt with briefly. Mould materials and mould coatings are considered.

Type of Ingot Moulds.

Sundry types of moulds are, and have been, used for casting aluminium rolling ingots. The chief types may be classified as follows :—

1. Flat (horizontal), open, stationary moulds.
2. Vertical, open, stationary moulds.
3. Tilting, vertical book moulds.
4. Vertical screw-operated moulds.

So-called box moulds, such as have been used widely in casting brass slabs, have found little application in aluminium practice. As is well known, the box mould consists of two halves (front and back), held together with bands and wedges. Water-cooled moulds of the Junker type, and the Durville mould set-up, have been tried for aluminium.

It is generally recognised that ingots for sheet rolling and wire bars are more dense, are more workable, and yield better products if cast vertically rather than horizontally. The directions refer to the longest axis of the ingot or bar. Also, with the vertical mould, it is desirable that the ingot should be bottom run—*i.e.*, filled from the bottom upwards, and the solidification should be progressively from bottom to top. A close and practical approximation to bottom running, with progressive solidification upwards, is had with the tilting, vertical book mould. In some designs of vertical moulds, bottom running is accomplished via a gate cut in the mould halves, and such a gate may be incorporated in the vertical tilting type of mould. Progressive solidification from the bottom upwards, in vertical moulds, may be promoted by the use of tapered designs (increasing the thickness at the bottom), and by water cooling suitably arranged.

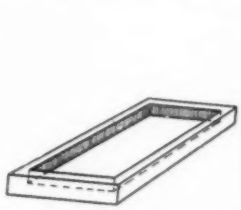


Fig. 1. Flat open stationary ingot mould.

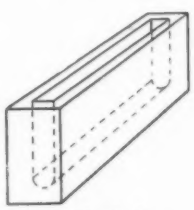


Fig. 2. Vertical stationary ingot mould.

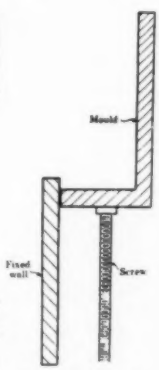


Fig. 3. Sketch showing vertical screw-operated ingot mould.

While all the variations of the principal classes of moulds listed above cannot be discussed here, typical examples of each may be given :—

Flat, Stationary Moulds.—The flat, open, stationary mould has found some application in the United States, particularly in mills attached to cooking-utensil plants, where the sheet and coil produced are consumed internally. Fig. 1 shows this type of mould. It consists simply of a cast-iron block, containing a suitable cavity. At one plant ingots measuring 2 × 12 × 18 in. are cast, using this type of mould. The wall thickness of the mould is about 1½ in. Moulds of this general type have also been used abroad for casting large ingots.

Vertical, Stationary Moulds.—Several types of vertical, stationary moulds have been employed in aluminium work. Usually, the width axis stands in a vertical position. Fig. 2 shows an example of this type of mould as used in an American mill for casting ingots 3 × 12 × 20 in. in size : the wall thickness of the mould is 2 in. In passing, it is of interest to point out that ingots are poured directly from the furnace into this type of mould.

In a patent, Angst* describes a mould in which ingots are cast with the width in a vertical position—*i.e.*, so-called edgewise-on. Angst's mould, incidentally, is of the adjustable type—the length and thickness of the ingot may be varied by shifting the end walls and one longitudinal wall. One fixed longitudinal wall is integral with the bottom.

* U.S. Patent 1,553,921, September 15, 1925.

Tilting, Vertical Book Moulds.—The tilting, vertical book mould consists of two separable halves, hinged at one edge and held together at the opposite edge by means of clamps and wedges, bolts and springs, or locking cams. As has been mentioned previously, this type of mould is used most extensively in aluminium practice. Illustrations of tilting vertical book moulds are shown in the drawings of

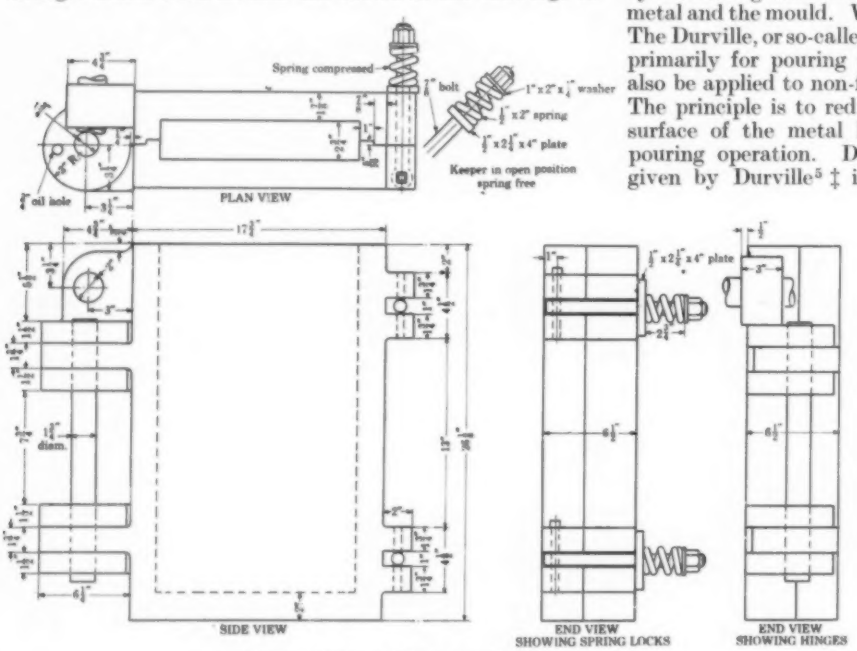


Fig. 4. Design of tilting, vertical book mould, uniform wall thickness.

Fig. 6. Tilting, vertical book mould, closed.

Figs. 4 and 5, and the photographs of Figs. 6 and 7. The chief variations in the design and set-up of this type of mould lie in the method of splitting, means for holding the halves together, method of mounting, and mechanism for actuating. In passing, it may be pointed out that one school favours the tapered mould—*i.e.*, thicker at the bottom than at the top,—while another school prefers to hold the walls uniform in thickness. Detailed descriptions are given below under the caption, "Construction of Book Moulds."

Vertical, Screw-operated Moulds.—In some plants, vertical moulds raised and lowered by means of a screw mechanism are used in casting large rolling ingots. Such moulds appear to have been employed largely in Continental Europe. One type of vertical screw-operated mould has three integral walls, one hinged side wall, and the fifth wall is a movable shutter or side which closes as the mould is lowered. The principle of this type of mould is illustrated in Fig. 3. In the operation, metal is introduced into the bottom of the mould over the shutter or fixed side, the mould being raised by the screw to the position indicated in the figure or a little higher. As pouring proceeds, the mould is lowered by means of the screw, the open side being progressively closed. This type of mould is used at the Vereinigte Leichtmetall-Werke G.m.b.H., Bonn, Germany. for casting ingots weighing up to about 2,000 lb.

Moulds of the vertical screw-operated type and means of closing the open side have been patented by Züblin.† In the specifications, it is indicated that the closing shutter consists of bars hinged so as to form an endless belt, supported on rollers or a frame. The mould is moved vertically on guides by means of a threaded spindle, motion being imparted by a hand-wheel. As the mould is lowered, the bars are brought into place on the open side and move with the mould. The joint between the bars and the mould is held tightly by means of springs pressing on the rollers.

† Swiss Patent 125,883, April 4, 1927; and British Patent 279,061, September 29, 1927.

Other Types of Moulds.—Water-cooled moulds have been mentioned above. The Junker type mould has been used considerably in casting brass slabs, notably in connection with induction-furnace melting. Description has been given by Junker[3] and others. The object of the water-cooled mould is to increase the rate of solidification—by increasing the difference in temperature between the metal and the mould. Water-cooled moulds have thin walls. The Durville, or so-called still-casting, process was developed primarily for pouring aluminium-bronze ingots, but may also be applied to non-ferrous metals and alloys in general. The principle is to reduce agitation by keeping the upper surface of the metal horizontal at all times during the pouring operation. Description of the process has been given by Durville[5] ‡ in published papers and in patent specifications. The water-cooling principle may be adapted with advantage to the tilting, vertical book mould. Pouring in moulds of this latter type closely approximates to the Durville idea.

Methods of mounting ingot moulds are discussed in a later section of the present article.

Construction of Book Moulds.

The main structural features of tilting, vertical book moulds are illustrated by the detailed drawings of the designs shown in Figs. 4 and 5. Fig. 4 shows a design of mould having walls of uniform thickness, for the production of ingots measuring $2\frac{3}{4}$ in. × 14 in. × 24 in., and weighing about 90 lb. Fig. 5 shows a design of mould having tapered walls, for the production of ingots measuring $4\frac{1}{4}$ in. × 12 in. × 24 in., and weighing about 116 lb. The salient features of design and construction of typical book moulds will be clearly evident from the drawings and the discussion given below.

Referring first to Fig. 4, it will be noticed that the cavity is designed for straight-edge ingots, but ingots with bulged edges of sundry shapes may be produced by suitable alteration of the narrowest wall faces of the cavity. The side walls are $1\frac{7}{8}$ in. thick all over, but the bottom wall is 2 in. thick. The ratio of wall thickness to ingot thickness is about as 1 : 1·46. Two hinges, cast integral with the separate halves or separate hinge parts bolted on, are provided on the back edge, as shown. In the mounting, the mould is hung on a horizontal bar by means of a suitable lug situated at the top of the back edge. This lug may be cast integral with the one half or bolted on. The mould halves are held together at the front edge by two locks or keepers, as shown. If a position is taken facing the locks, the right-hand half of the mould is the fixed half (being held in position by the lug suspension), and the left-hand half is the movable side. Regarding the method of splitting: the mould shown is split in the centre line

‡ U.S. Patent 1,189,548, July 4, 1916.

of the joined halves, but an offset notch is provided to improve the fitting and prevent leakage of metal. Moulds of this type may be split so that one side wall and both end walls are contained in one half and the other side wall and the bottom wall in the other half. Or they may be split on the diagonally opposed corners. The question of notching is debatable.

Referring to Fig. 5, this shows a tapered mould of the tilting, vertical book type. The side walls vary in thickness from 3 in. at the top to 5 in. at the extreme bottom of the mould, while the bottom wall is 3 in. thick. Variations will be noted in the design of the hinges and the locking device as well as in the splitting and notching, as compared with the mould shown in Fig. 4. Fig. 6 shows a photograph of a mould similar to that detailed in Fig. 5, but of lighter construction — *i.e.*, thinner walls. This is seen in the closed position. Fig. 7 shows the same mould in the open position. The pipe fitting and hose connection for the water spray will be noted.

Considerable difference of opinion exists regarding the proper thickness of cast-iron moulds in relation to the ingot thickness. With uncooled moulds the temperature attained by the wall face can be reduced by increasing the thickness, but a limit is shortly reached beyond which any further increase is of no practical value. Aside from the effect of thickness on solidification rates, the mould must be of sufficient thickness to stand severe usage. If the walls are too thin, the mould has a tendency to crack, break, or wear out rather quickly. Increasing the thickness beyond that required for rapid solidification and durability simply increases the weight, bulk, cost, and difficulty of handling. It is to be understood that external cooling with a water spray is used with tilting vertical book moulds where the operation is continuous. Also, the upper part of the mould may be lagged with insulation, the bottom part being sprayed in order to promote progressive upward solidification. American practice appears to favour thicker mould walls than the British or Continental European.

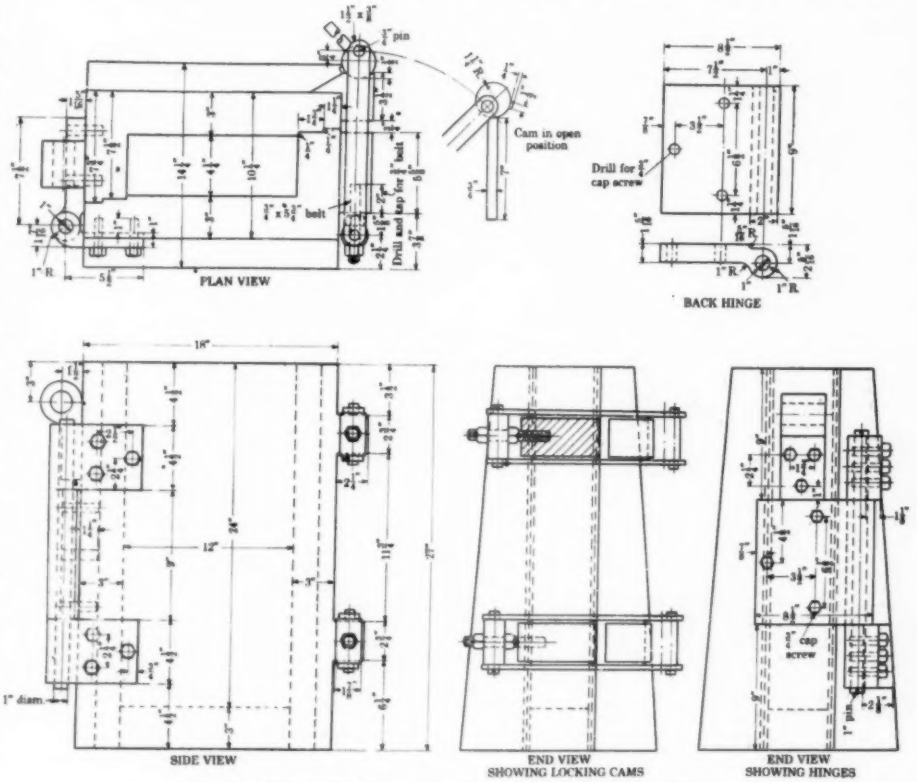


Fig. 5. Design of tilting, vertical book mould, tapered walls.

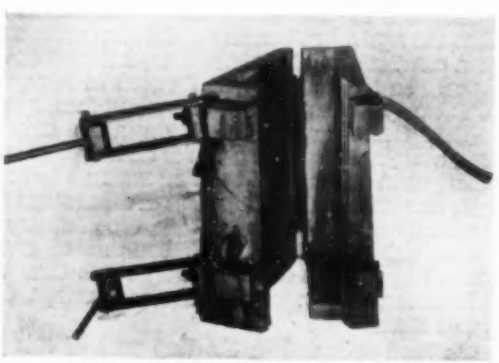


Fig. 7. Tilting, vertical book mould, open.

The object of the tapered mould (thick end down) is two-fold—viz., to promote solidification from the bottom upwards, and to permit faster pouring. In running a hotter top and a colder bottom (heavily water sprayed), the writer has found that feeding is better, sounder ingots can be produced, and the pouring rate can be much increased.

Some operators favour the use of a bottom pouring gate in operating the tilting, vertical book mould. The gate is cut in both halves of the cavity. The writer has been unable to find proof that such gated moulds give any better results than the ungated type. Additional expense and increased amount of scrap result, of course, from the use of gated moulds.

In a patent by Allison,‡ a hinged, swinging book mould of the vertical type is described; this was designed especially for brass slabs. In another patent, Scott§ specifies the use of links in holding mould halves. In pouring dual ingots of the Alclad type in tilting, vertical book moulds, Carbis¶ specifies holding the coating plates against the mould faces by suction. This is, of course, unnecessary, since the plates may be cut to fit the mould and simply pushed into place with a press fit. A mould and mounting is shown in Carbis' patent.

Mould Mountings and Fittings.

Methods of mounting ingot moulds vary considerably, depending in large part on the type of mould. In the case of flat, open, stationary moulds, the separate blocks may be placed on the floor or on a suitable raised pipe, I-beam, or table structure, supported by legs. Care should be taken that the moulds are maintained level. The operation of pouring is awkward when the moulds are placed on the floor. A good type of mounting for flat, open moulds consists of an I-beam structure, supported on legs, and fitted with bearings and suitable gearing, so that it can be turned over. A set of, say, five or more moulds is mounted on each side of the I-beam. This arrangement is referred to as the double-bank up-setting type.

The bibliography will be appended with the continuation of this part in the next issue.

‡ U.S. Patent 954,368, April 5, 1910.
§ U.S. Patent 1,245,046, October 30, 1927.
¶ Canadian Patent 343,100, March 18, 1930.

Vanadic Pentoxide.

Its Recovery from Zinc-Iron Vanadate.

THE ores of the zinc-lead deposit in Northern Rhodesia owned by the Rhodesia Broken Hill Development Co., Ltd., contain vanadium in the form of descloizite and vanadinite. In the extraction of the zinc from the ore for electrolytic recovery, the vanadium is dissolved and its recovery is now effected in the form of fused vanadium pentoxide. The vanadium is precipitated from the zinc solution as a zinc or iron vanadate, and is subjected to retreatment for the recovery of the vanadium in a purified form.

The precipitate is removed from the solution by filtration in pressure filter presses, the filtrate being returned to the zinc circuit, and the cake washed with water to remove most of the soluble zinc. When washing is complete the precipitate is discharged from the press and transported to a storage bin, from whence it is fed, together with water, to a grinding mill, where the cake is converted to slurry. The mill discharge is pumped to storage tanks, in which agitation is maintained, and from which pulp is withdrawn as required, to the first stage of purification, which is a solution of the vanadium values in caustic soda. The latter reagent is prepared on the plant by reaction between lime and soda carbonate in the well-known manner, and is produced as a caustic liquor containing at least 75 g.p.l. NaOh.

Proportions of vanadate slurry and caustic solution, depending on the relative density and strength, are mixed in an iron tank provided with agitation and means of steam-heating. The temperature is raised to nearly 100° C., and agitation is continued until the reaction is complete, approximately 1 to 2 hours. The vanadium dissolves as a sodium vanadate, and the zinc, iron, etc., mostly remain insoluble as hydroxides.

The pulp is then pumped to a filter press and the purified solution sent on to the next stage of treatment. The residue in the press is washed with water and then discharged and transported to a pug-mixing machine, which delivers into an agitation tank, where the residue is suspended in zinc solution and then pumped back to the zinc circuit for recovery of that metal and utilisation of its basiscity for further precipitation purposes.

The sodium vanadate solution is then sent to the canadic hydrate precipitation tanks, where sulphuric acid is added until free acidity is about 5 g.p.l. H_2SO_4; steam is then turned on and the temperature allowed to rise to a maximum, about 95° C. The solution may be heated prior to addition of acid, or acid added during heating, whichever method may be most convenient. Acid is added from time to time as may be necessary to maintain at least 5 g.p.l. excess, though excess up to 25 g.p.l. can be added without detriment. As the temperature rises, the vanadic hydrate will precipitate and maximum precipitation will be obtained at boiling point, the final temperature of the solution being such as to give an economic precipitation consistent with the cost of steam heating. Excess of acid generally lowers the precipitation efficiency, but may give a more pure product, so the excess acid at which the precipitation is conducted is regulated to the amount required to produce maximum precipitation at the desired purity. The residual impurities in the solution remain dissolved, and the vanadic hydrate is practically pure.

When precipitation has reached the desired standard, the pulp is filter-pressed in a wooden-framed press. The filtrate is either run to waste or is retreated for its vanadium content, depending on the amount of the latter. Such retreatment may be simply returning to the zinc circuit at a suitable point if the content of other soluble salts permit, or may be a precipitation with lime, which precipitate would then be retreated in the causticising step and the vanadium recovered in the caustic solution during the use of the latter to dissolve the vanadium from the zinc vanadate.

The vanadic hydrate precipitate in the press is then washed until all soluble salts are removed, the wash being used in a counter-current manner and the strong wash returned to the precipitation circuit, after which the cake is discharged to a bin and then fed to a gas-fired melting furnace, where first the moisture and combined water are drawn off, and then the dehydrated material fused. The fused oxide discharges more or less continually into moulds, from which it is discharged, crushed, and bagged.

The grade of oxide produced is at least 90% V_2O_5, and may be 95% or better. It is practically free from phosphorus and sulphur, the balance being made up of alkalies with small amounts of silica and iron.

This method of treatment has been developed by the general manager of the Rhodesia Broken Hill Development Co., Ltd., Mr. R. H. Stevens, who was responsible for the original zinc-leaching process, which is now the principal interest of the company.

The Ore Deposits.

The ore deposits of Broken Hill occur in a dolomitic formation, and have originated by the replacement of susceptible beds in the dolomite by cross-cutting mineralising fissures. They take the form of successive lenses bearing slightly South of West by North of East, and dipping steeply to the North conformably to the strike and dip of the enclosing dolomite. The mode of occurrence of the oxidised and primary ores is characteristic. The more important ore bodies always consist of two parts: a central portion or core of massive sulphide ore zinc blend and galena enclosed within an envelope or "shell" of oxidised ore, principally "zinc silicate."

"Zinc silicate" is the local designation for the bulk of the oxidised ore, and consists of quartz, iron oxides, and zinc silicate, with lesser amounts of zinc carbonate, lead carbonate, and vanadium minerals. It is very rich, assaying from 30 to 55% of zinc and lead combined.

The occurrence of vanadium in the oxidised ores is of special interest. The rich vanadium ores have a well-defined marginal relation to the oxidised ores, being developed on the margins of the latter and largely in the broken ground between the massive oxidised ores and the dolomite, as well as in open fissures and cavities. The whole of the oxidised ores also average a small percentage of it. Descloizite with lesser amounts of vanadinite constitute the vanadium-bearing minerals.

Some Factors Influencing the sizes of Crankshafts for Double-acting Diesel Engines.

THE general procedure for determining the diameter of a shaft subjected to combined bending and torsion is to calculate the equivalent bending or twisting moment, and to use a constant working stress irrespective of the type of engine. In the method put forward in a paper by Mr. S. F. Dorey, M.Sc., Wh.Ex., at a recent meeting of the North-East Coast Institution of Engineers and Shipbuilders, a different stress is used for each type of engine, depending upon the ratio of twisting moment to bending moment, and also on the fluctuations of shear stress at the most severely stressed crank. Thus, the diameter of a crankshaft subjected to large fluctuations of stress is ascertained by using a lower working stress than in the case of a shaft not so severely stressed, yet having the same maximum stress.

The method indicated in the first part of this paper shows how the strength of crankshafts can be ascertained from a knowledge of the fatigue properties of materials at various ranges of stress, and has been used to determine suitable diameters of crankshafts for double-acting Diesel engines, based on previous experience with steam reciprocating engines and single-acting Diesel engines. The results indicate that for engines having a small number of cylinders the working stress permissible should be appreciably less than for engines having a large number of cylinders for the same factor of safety.

The Phase-Theory Basis of Ageing of the Duralumin Type in the Ternary System*

In multiple systems, to which Duralumin belongs, several types of crystals may separate out alongside one another. The view has been expressed that the change in concentration of the supersaturated solid solution, due to the separation of the one type of crystal, can influence the separation of the other type, and the way in which this influence can affect the course of the separation is considered.

IN most of the known binary alloys that are capable of "improvement," the limited solubility of the added metal in the major constituent increases as the temperature rises. This is represented diagrammatically in Fig. 1. When heated to the temperature t_2, the alloy consists of the homogeneous solid solution A. If it be now rapidly cooled to t_1 or below, with no separation of B during cooling, it is possible for separation of crystal type B to an amount corresponding to the length b_1x_1 to occur at t_1. The point b_1 fixes the maximum solubility of B in A, if fusion is to take place at higher temperatures: on the other hand, the appearance of a new phase may increase the solubility. Polymorphous transformation of the major constituent is of special importance when the type of crystal stable at the higher temperature has a greater solubility for B. Fig. 2 shows this case, which is actually met with in the alloys of iron with carbon, nitrogen, and copper, for example. In such cases the γ-crystal stable above the three-phase equilibrium line may be wholly or partly converted into the α-crystal stable below this line without

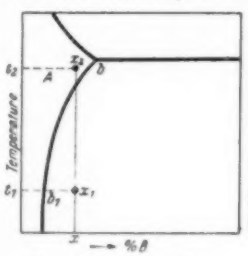


Fig. 1.—Saturation Curves for one Constituent of a Solid Solution.

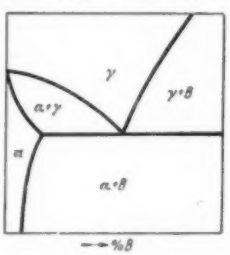


Fig. 2.—Polymorphous Transformation of a Solid Solution—e.g., an Iron Alloy.

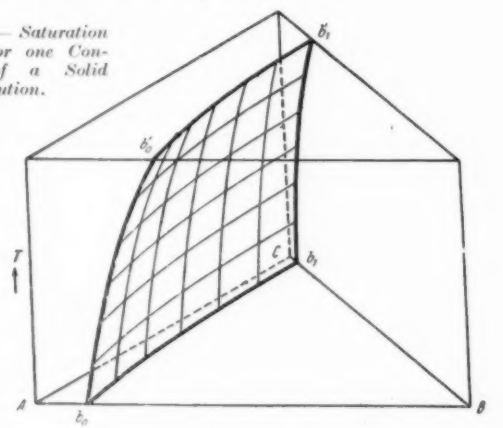
the supersaturation being raised, so that in the case of the iron-carbon alloys the α-crystal may hold carbon in solid solution to an amount one hundred times its saturation at room temperature.

In multiple systems, to which most alloys, and in particular duralumin itself, belong, several types of crystals may separate out alongside one another. In this connection the new viewpoint is that the change in concentration of the supersaturated solid solution, due to the separation of the one type of crystal, can influence the separation of the other type. In what follows it will be shown, with the aid of the theory of heterogenous equilibrium, in what way this influence can affect the course of the separation. Consideration will be limited to the ternary system.

Dependence of the Saturation Surfaces of a Ternary Solid Solution on the Temperature.

Fig. 3 shows the saturation surface $b_0b_1b'_1b'_0b_0$ of the solid solution A for B in the ternary range, developed from the saturation curve of A for B in the binary system, Fig. 1, it being assumed that the third material C remains in solid solution in A throughout. This saturation surface divides the ternary-condition area into a homogeneous zone and a two-phase zone. At every point x of the two-phase zone a saturated solid solution b is in equilibrium with B-crystals. All three points lie on an isothermal straight line, which will be called the conode (Fig. 4). A change in the composition of an alloy along a conode does not affect the composition of the solid solution or of the crystal type B, but only the relative amounts of these. For the sake of simplicity it is assumed here and in the sequel, that the crystal types B and C existing in equilibrium with the solid solution A are not mixed crystals.

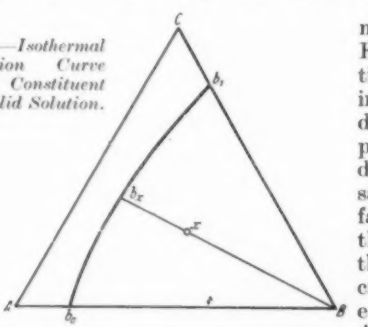
Fig. 3. — Saturation Surface for one Constituent of a Solid Solution.



If A has also only a limited solubility for the component C, the saturation surface of A for B will be intersected by that for C at the spatial curve aa', on which A is saturated with both B and C (Fig. 5). For this reason, part of the saturation surface is unstable, this being indicated in Fig. 5 by the less heavy lines as compared with those showing the stable portion.

In Fig. 5 the solubility of both B and C in A increases along the doubly saturated edge aa' as the temperature rises. However, it is also possible for the solubility of the one type of crystal to increase and for that of the other to decrease, or for them to pass through extreme values.

Fig. 4.—Isothermal Saturation Curve for one Constituent of a Solid Solution.



In the isothermal section, Fig. 6, saturation curves which intersect at the doubly saturated point a are drawn from the saturation surfaces. Hence, in the triangle a B C three types of crystal are in equilibrium. According to Schreinemakers[1], the unstable portions of the saturation curves close to the doubly saturated point a either both lie in the three-phase zone a B C, Fig. 6, or that for B lies in the two-phase zone A + C and that for C in the zone A + B, Fig. 7. This theory does not hold, however, for unstable doubly saturated points in a miscibility gap.

* Translated from "Die phasentheoretischen Grundlagen der duraluminartigen Vergütung im Dreistoffsystem," *Zeits. f. Metallk.*, September, 1930, by I. Boodson.

[1] Roozeboom, *Die heterogenen Gleichgewichte*, vol. III., p. 260, *et seq.*

The saturation curves may, if continued, intersect the conodes of the doubly saturated point a, as those for the super-saturated solid solution A are not distinct from the other conodes. Both saturation curves end in the side B C[2].

Isothermal Separation of Two Types of Crystal from a Super-saturated Solid Solution.

When, by heat-treatment of some sort, a super-saturated solid solution A of the composition x has been produced, the question arises: Along which curve in the concentration diagram, Fig. 6, will the composition of the super-saturated solid solution change during the isothermal separation of B and C, before it finally reaches the doubly saturated

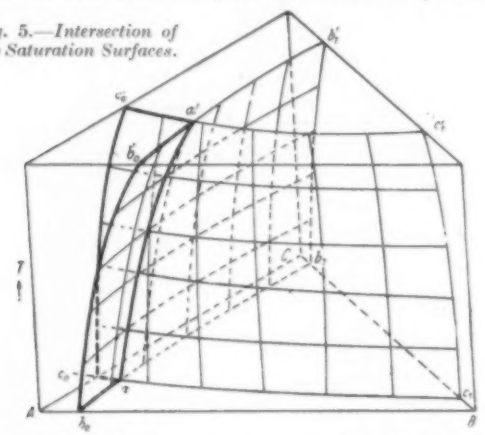


Fig. 5.—Intersection of two Saturation Surfaces.

point a? It is in no way necessary that this separation curve should be the line joining x and a. If A and C form a homogeneous solid solution, the saturation curve of A for B divides the equilibrium diagram into a homogeneous zone of solid solution A and a two-phase zone in which the saturated solid solution A is in equilibrium with the crystal type B, Fig. 4. Owing to the separation, the super-saturated solid solution changes its composition along the conode B x beyond x till the point b_x is reached. The amount which can separate at the point x is—

$$u_B(x) = \frac{x\,b_x}{B\,b_x} \quad . \quad . \quad . \quad . \quad (1)$$

Should the components A and C of the system be incompletely soluble in each other, the saturation curve of A for B will be partly unstable, as has already been stated. In Figs. 6 and 7 $b_0 a$ is the stable, $a\,b_1$ the unstable portion of the saturation curve for B, and $c_0 a$ and $a\,c_1$ the corresponding portions of the curve for C. If no separation of C occurs, the considerations based on Fig. 4 apply equally well, whether b_x lies on the stable or the unstable portion of the saturation curve. The amount $u_B(x)$, and likewise $u_C(x)$, is therefore wholly independent of whether separation of other types of crystal can occur; $u_B(x)$ and $u_C(x)$ are only dependent, therefore, on the position of the point x, which may be the beginning or any other point of the separation curve. The sign for $u_B(x)$ is undefined, but should be taken as positive when separation of B occurs. Hence $u_B(x)$ is positive when x in Fig. 4 lies between b_x and B, and negative when b_x lies between x and B, as then solution of the B crystal occurs.

It follows that the speed $v_B(x)$ at which B separates out is a vector to the direction of the conode B x. The absolute amount of the vector is the quantity of B which separates out in unit time. $V_B(x)$ may be split into two factors, one a function of the amount which can separate out $[f_B\,u(x)]$ and the other a function $g_B(x)$, which includes the speed of diffusion, the number of embryos present and originating, etc., so that the speed at which B and C respectively separate out may be expressed as—

$$v_B(x) = f_B\,[u_B(x)]\;g_B(x)$$

and

$$v_C(x) = f_C\,[u_C(x)]\;g_C(x) \quad . \quad . \quad . \quad (2)$$

These expressions are based on the assumption that the functions $g_B(x)$ and $g_C(x)$ are independent of each other. This is not necessarily the case, but, as the mutual influence will never be very great, this simplification is permissible in order to make consideration of the question not too involved.

In Fig. 8 the vectors $v_B(x)$ and $v_C(x)$ are shown for different positions of x. The direction of the separation curve is obtained by vectorial addition of $v_B(x)$ and $v_C(x)$. For these only the position of x relative to the saturation curves is of importance, and the limits of the three-phase zone A + B + C are consequently not shown in the figure.

In the unsaturated solid solution zone A $b_0 a\,c_0$A, Fig. 8 only solution of B and C can occur, so far as the two crystal types are at all present. This case is hardly likely to occur, and will not be further considered. Along the limiting curves $b_0 a$ and $c_0 a$ of the stable homogeneous range neither solution nor separation can occur. On the unstable portion $a\,b_1$ of the saturation curve for B, $v_B(x) = 0$, whilst $v_C(x)$ has a finite value (point x_1, Fig. 8). The tangent $x\,z$ to the separation curve has, therefore, the direction of the conode C x at points on the unstable portion of the saturation curve for B. If the point x lie between the unstable portions of the saturation curves for B ($a\,b_1$) and C ($a\,c_1$), the tangent $x\,z$ to the separation curve gradually changes its direction from that of the conode C x_1 to that of the conode B x_4 as the point x moves along the conode B x from x_1 to x_4 (Fig. 8).

In the area $a\,c_1$ B$b_0 a$ only B can separate, and the separation curve at x_5 has the direction of the conode Bx_5 till it meets the saturation curve for C, from which point on, both crystals can again separate out. As the saturation curve for B is approached, the tangent $x\,z$ to the separation curve gradually changes its direction to that

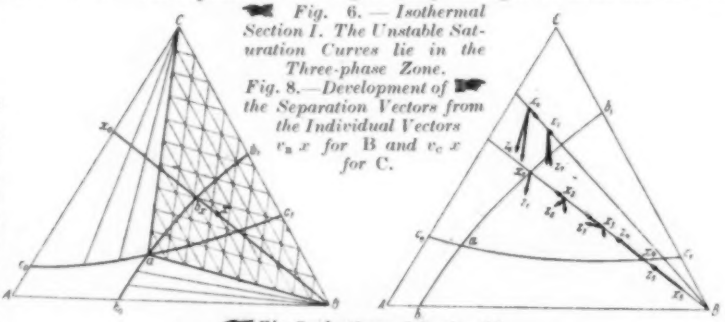


Fig. 6. — Isothermal Section I. The Unstable Saturation Curves lie in the Three-phase Zone.

Fig. 8.—Development of the Separation Vectors from the Individual Vectors $v_B\,x$ for B and $v_C\,x$ for C.

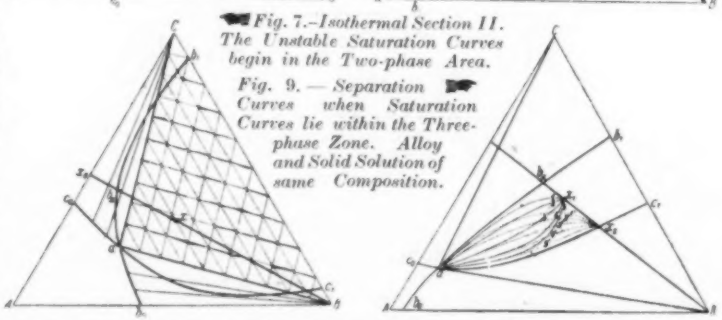


Fig. 7.–Isothermal Section II. The Unstable Saturation Curves begin in the Two-phase Area.

Fig. 9. — Separation Curves when Saturation Curves lie within the Three-phase Zone. Alloy and Solid Solution of same Composition.

of the conode for C, attaining this direction at the point of intersection with the saturation curve a b. If now, any separated B crystals are present, these are dissolved; hence $v_B(x)$ is negative at the points x_6 and x_7 (Fig. 8). Similar reasoning applies to the solution of C and the separation of B in the area $a\,c_0$C $b_1\,a$.*

[2] At any point in the side A C the plane tangential to the ξ-surface of the solid solution A in both the stable and the unstable zones is perpendicular to the base. Hence the tangent of the ξ-value of B to the ξ-surface of the solid solution A can never touch the latter surface at the ξ-values of the side A C. The saturation curves $a\,b_1$ and $a\,c_1$ cut the side B C.

* Translator's Note.—This is in accord with the original, but it is obvious from the preceding text, and from the figure, that solution of B and separation of C occur in this area.

In order to be able to construct the separation curve for any special case, certain assumptions must be made in respect to the functions f and g in equations 2. Let us put

$$f[u(x)] = u(x),\ g_B(x) = b, \text{ and } g_C(x) = c \ldots (2A)$$

where b and c are constants. If, however, a change from separation to solution occurs in a separation curve, the values of the constants will also change as a general thing. With the above assumptions equations 2 become

$$v_B(x) = b\,u_B(x)$$

and

$$v_C(x) = c\,u_C(x) \quad \ldots\ldots\ldots (3)$$

This signifies that the speed of separation is proportional to the amount which can separate and that the quotient $\frac{b}{c}$ is constant during the separation, provided no change in the sign occurs.

In the binary system the analogous relation is—

$$v(x) = \frac{dx}{dt} = k(a-x)$$

or integrated

$$x = a\,e^{-kt}.$$

different positions of x and five different separation ratios, $\frac{b}{c}$. At the point x_2 the direction of all the separation curves (dotted) is that of the conode B x_2. If x lie inside the zone, the tangents fron x to the separation curves differ from one another. The angle $b_x x_1 c_x$ between the conodes is divided by the tangent $x_1 r$ (not shown in the figure) in the following ratio, readily deduced from the vectorial equations—

$$\frac{\sin b_x x_1 r}{\sin c_x x_1 r} = \frac{b\,x_1 c_x}{c\,x_1 b_x} \quad \ldots\ldots\ldots (4)$$

The curves all end in the point a, the stable saturation point of B and C. The tangent from a to the separation curves is independent of the position of x, and divides the angle between the tangents from a to the saturation curves in the ratio $b : c$.

In Fig. 10, separation curves are drawn for the case in which the saturation curves begin in the two-phase zones. Two types of curve must be distinguished. The first type—

Curve 1 : $\frac{b}{c} = 1$ $\frac{b'}{c} = 1$
" 2 : $\frac{b}{c} = 2$ $\frac{b'}{c} = 1$
" 3 : $\frac{b}{c} = 4$ $\frac{b'}{c} = \frac{1}{2}$
$\frac{b'}{c} = 1$
$\frac{b'}{c} = 2$
4 : $\frac{b}{c} = 8$

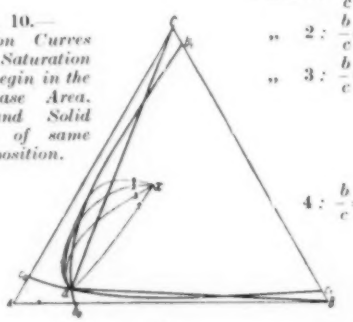


Fig. 10.—Separation Curves when Saturation Curves begin in the Two-phase Area. Alloy and Solid Solution of same Composition.

Curve 1 : $\frac{b'}{c} = -\frac{b}{c} = -1$
$\frac{b'}{c} = -\frac{b}{c} = -2$
$\frac{b'}{c} = -\frac{b}{c} = -4$

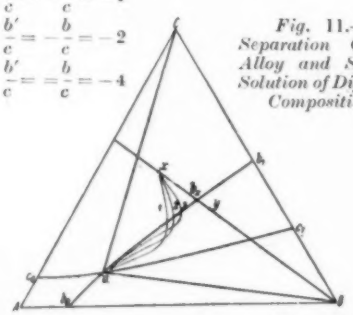


Fig. 11.—Separation Curves Alloy and Solid Solution of Different Composition.

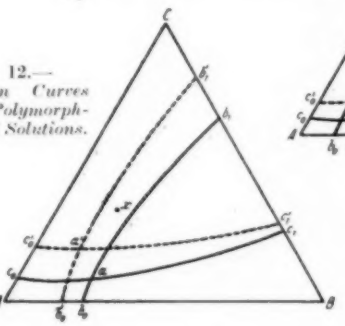


Fig. 12.—Saturation Curves for two Polymorphous Solid Solutions.

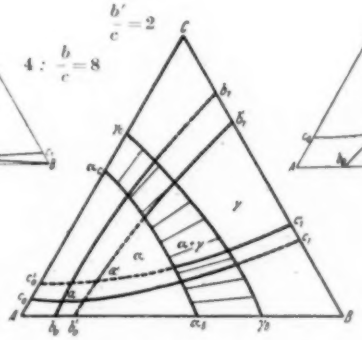


Fig. 13.—Saturation Curves for a Polymorphous Transformation of the Solid Solution in the Unstable Range.

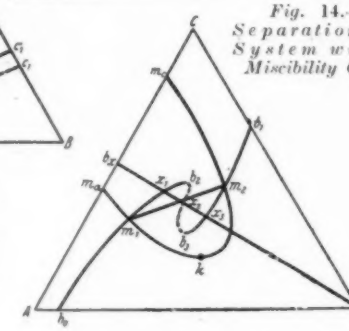


Fig. 14.—Separation in a System with a Miscibility Gap.

According to Frankel's observations,[3] this equation enables the waning of the separation with time to be calculated with a close approximation. The representations of the course of the separation by the above pair of equations (3) may, therefore, be assumed to be fairly correct.

When considering the separation curves, two cases must be distinguished :—

1. When the super-saturated solid solution x and the alloy y are of the same composition when separation begins.

Fig. 9 shows a case in which the saturation curves lie within the three-phase zone. In no position of x can solution of either component occur, but only separation. In the two-phase area $b_0 a\,B\,b_0$ and in the portion $a\,c_1 B\,a$ of the three-phase zone only separation of B can occur, and in the corresponding areas $c_0 a\,C\,c_0$ and $a\,b_1\,C\,a$ only separation of C. The separation curve in a two-phase zone remains in this zone throughout its course, and is represented by the conode of the crystal type capable of separating at this point. In the other two zones, in which separation of but one crystal type occurs, the composition likewise changes along the conode until the saturation curve for the other crystal type is reached. Between the two saturation curves $a\,b_1$, $c_1 a$, both crystal types may separate.

In Fig. 9, in which the saturation curves are in the three-phase zone, the separation curves are shown for two *e.g.*, curve 1,—with the separation ratio $\frac{b}{c} = 1$, does not cut the unstable portion of the saturation curve. This type requires no special consideration. The second type cuts the unstable portion of the saturatior curve. As already explained when discussing Fig. 8, the conode at the point of intersection is also the tangent to the separation curve. Solution of B takes place along the further course of the separation curve up to the point a. In Fig. 10 three different solution-separation ratios, $\frac{b'}{c} = 2$, 1, and $\frac{1}{2}$, are shown for the separation ratio $\frac{b}{c} = 4$ (curve 3), whilst for the separation ratios $\frac{b}{c} = 2$ (curve 2) and $\frac{b}{c} = 8$ (curve 4) only the solution-separation ratio $\frac{b'}{c} = 1$ is shown. The solution-separation curves enter point a with tangents which divide the supplementary angle to the angle between the tangents to the saturation curves at a in the ratio $\frac{b'}{c}$.

There remains the question as to when the separation curve will cut the saturation curve. This will obviously happen when the separation curve already cuts the limiting conode of the three-phase zone.

[3] *Z. f. Metallk*, vol. 12 (1920), p. 225.

2. When the super-saturated solid solution x and the alloy y are of different composition when separation begins. This case is met with when the alloy y does not lie in the homogeneous zone of the solid solution A at the quenching temperature to which it was heated in order to produce the super-saturated solid solution, or when the period of heating was insufficient to bring about complete solution. The first case occurs when the solubility of B in A increases along the saturation surface. Only those cases are of interest, however, in which the crystal type not in solution goes wholly or partly into solution again at the lower ageing temperature. This, for example, is the case when the alloy y lies between the two saturation surfaces $a\,b_1$ and $a\,c_1$, Fig. 11, but the super-saturated solid solution x lies outside this area. In order to explain the circumstances, we may assume that only one type of crystal—*e.g.*, B—has separated, and that y and x lie on the conode B b_x. In the case shown in Fig. 11, b_x lies between x and y, but it is also possible for y to lie between x and b_x. In Fig. 11 the separation curves for $\frac{b'}{c} = 2$, 1, and $\frac{1}{2}$ and $\frac{b}{c} = \frac{b'}{c}$ are shown, the composition of the alloy being y. The tangents at x again obey the sine relation (eq. 4). Up to the point of intersection with the saturation curve $a\,b_1$, B dissolves and C separates out (*c.f.* points x_6 and x_7, Fig. 8). At the point of intersection with the saturation curve the conode is tangential to the separation curve. From this point on the curves do not differ from those in Fig. 9.

The noteworthy feature of the cases in this section is that the beginning of separation of C is bound up with solution of B. These cases may, therefore, lead to quite complicated curves for change in properties. That solution does take place can be established by increasing, by prolonged annealing, the grain size of the crystal type not dissolved at the annealing temperature, so that a noticeable reduction in the speed of solution, which may be assumed to be proportional to the surface, occurs. It would pay to examine whether some of the anomalies, in particular the original drop in the electrical conductivity, in the "improving" of duralumin can be explained in this way.

Discussion of Some Special Cases.

The most complicated cases can be readily dealt with by the use of these simplifications. For a polymorphous transformation of the solid solution A, such as is shown for the binary case in Fig. 2, the following cases must be distinguished :—

1. The γ-form existing at the higher temperature is wholly transformed into the α-form stable at the lower temperature before separation of B or C occurs. This case differs in no way from those already discussed.

2. The transformation $\gamma \rightarrow \alpha$ ceases, and both B and C separate out from the solid solution γ, in amounts corresponding to the saturation curves valid for the latter. This case is also no different from those already considered.

3. In addition to the transformation $\gamma \rightarrow \alpha$, separation of B and C from both types of crystal may occur. The separation curves for the γ- and α-forms must then be considered separately, and the values multiplied by the percentage content of the amount of γ and α present at the individual points of the curves, in order to give the amount of material separated. How complicated these cases may be is shown by Fig. 12, in which the unbroken lines represent the saturation curves for the α-form, and the broken those for the γ-form. At the point x, B separates out from the γ-form, and at the same time dissolves in the α-form.

4. The equilibrium between the α- and γ-forms cuts the isothermal triangle for the separation temperature in the unstable range. In the γ-zone (Fig. 13) only separation of B and C from the γ-solid solution occurs, till the shaded portion, in which the γ- and α-forms exist in unstable equilibrium, is reached. In this zone, between the curves $\alpha_B\,\alpha_C$ and $\gamma_B\,\gamma_C$, separation of α as well as of B and C is possible. Finally, for the α-zone, what has been said of case 3 applies.

The shape of the two-phase zone $\alpha + \gamma$ may naturally be even more complicated, but details are lacking for the discussion of such cases. It must be emphasised, however, that these cases are of importance in the transformation of alloy steels during hardening and tempering.

A further and more difficult case arises when a gap occurs in the unstable solid solution range at the temperature of separation. Such a case is shown in Fig. 14. The miscibility gap $m_a m_c$ in the system A—C is closed by the addition of B. At the critical point k, the two solid solutions are equal. In the non-miscible range the saturation curves for the A and C solid solutions form a single curve. The conode B b_x cuts the saturation curve at three points—x_1, x_2, x_3. To bring out the significance of these points of intersection, the section B b_x, through the ξ-surface of the solid solution is reproduced in Fig. 15.

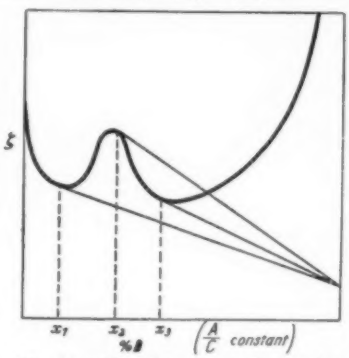


Fig. 15.—The G-curve on the Section B b_x. Fig. 4.

Corresponding to the points of intersection there are three tangents from ξ-B, the ξ-value of the B-crystals, to the ξ-curve of the A (C) solid solution which touch the curves at the concentrations x_1, x_2, and x_3. Hence the point x_2 corresponds to a labile equilibrium, since any slight displacement of the concentration reduces the ξ-value, and so increases the stability of the system. The point x_2 has, moreover, a special significance as limit, since in the range between x_1 and x_2 the concentration of the solid solution can only change from x_1 to x_2, and therefore separation of B occurs. Between x_2 and x_3 an alteration to x_1 would require an increase in energy, at least at first. Should separated B crystals be present, these will dissolve up as the concentration changes to x_3. Hence, there exists in this zone a metastable state, and some new happening is required to bring about any further change. This may be the splitting up of the solid solution, which possibility has up to the present been disregarded. Other possible causes are slight temperature changes or even plastic deformation of the alloy. In this zone it obviously requires only a slight impulse to change solution to separation.

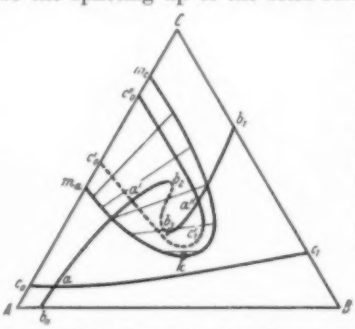


Fig. 16.—Separation in a System with a Miscibility Gap within the Unstable Range.

Should there also be present a crystal type C for which the solid solution A has likewise a saturation curve, further points of intersection with the saturation curves occur and the stability of these must also be investigated. In Fig. 16 the saturation curve for C consists of two distinct branches, one the curve $c_0\,a\,c_1$, which is stable where separation of C only occurs and has an unstable portion only in relation to the separation of B, the other the unstable U-shaped curve $c_0'\,c_1'\,c_0''$, which is made up of a metastable portion $c_0''\,c_1'$ (indicated in Fig. 16 by an unbroken line), and a labile portion $c_0'\,c_1'$ (indicated by the broken line). If in Fig. 15 B be replaced by C, the curve will represent a section through the C-triangle of the ξ-surface. The point x_1 then belongs to the saturation curve $c_0\,a\,c_1$, the point

(*Continued on page* 182.)

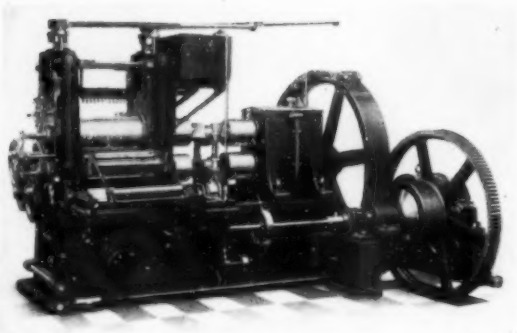


Fig. 2.—Typical Intermediate Mill.

ROLLING—— METAL FOIL*

By

C. E. Davies, A.M.I.Mech.E.

A VERY considerable demand exists for foil containing a high percentage of lead for lining tea chests. This class of foil is now satisfactorily rolled in widths up to 26 in. and wider, in continuous coils and in various thicknesses, generally designated 3 oz., 2 oz., and 1 oz. lead, corresponding to thicknesses of 0·003 in., 0·002 in., and 0·001 in. respectively. For this wide foil extremely powerful breaking-down mills are required; with larger rolls than those fitted to the mill illustrated by Fig. 1, and described in the earlier part of this article, usually rolls 14 in. to 15 in. diameter, 30 in. to 32 in. long are employed for rapid reduction of the heavy wide slabs of lead, which may be upwards of 2 cwt. in weight. Fig. 6 illustrates the latest design for mills of this type as recently built by Messrs. W. H. A. Robertson and Co., Ltd., Bedford, having hardened steel rolls of 15 in. diameter.

To facilitate handling the heavy slabs during the several passes, these breaking-down mills are reversible, being driven by a reversible motor with automatic contactor switches and master reversing controller. Rolling is consequently carried out in both directions alternately, and long roller tables with rollers running in ball bearings are provided on both sides of the rolls for the run-out of the metal before it is thin enough to coil. Extremely heavy reductions per pass are effected, and a slab over 1 in. thick is reduced to about 0·025 in. thick in a very short time. Specially powerful coiling drums are mounted on adjustable cross-slides on both sides of the rolls, for coiling the metal as soon as it is thin enough, the coiling tension being regulated as for other similar mills by friction clutch with micrometer adjustment.

Removable and interchangeable spools are employed, and special driving mechanism is provided for these, so that they may be easily and quickly removed and refitted. As both coilers must alternately operate as unwinding reels, an adjustable friction brake must be fitted to each, with independent fine adjustment. When the coilers are in operation, sections of the roller tables are swung clear, these sections being hinged and balanced for the purpose. The roll bearings are of special design, internally water-cooled and provided with automatic forced lubrication to ensure cool running under heavy pressure. The top roll is raised and lowered rapidly by means of an auxiliary electric motor operating both screws through totally enclosed machine-cut worm gearing. This must be controlled by a "push-button" switch conveniently placed, giving complete and accurate roll setting with the minimum loss of time. Independent adjustment of either screws for parallel setting of rolls is effected by means of clutches operated by hand levers, this gives the finest possible adjustment of either end of the roll at will.

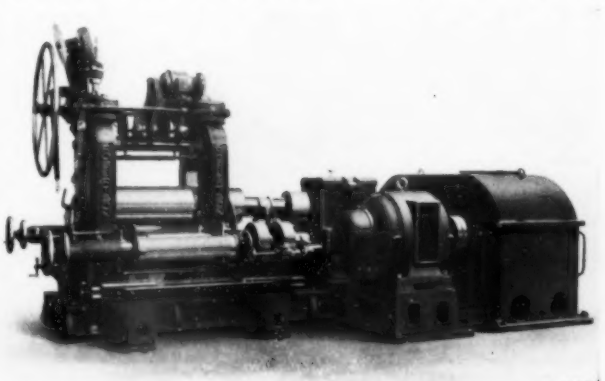
A graduated indicator dial is mounted in an easily visible position above the mill, with two pointers geared to the roll-adjusting screws, one indicating large changes of roll position and the other the finest limits. Alternative hand gear is provided, with a clutch to disconnect the handwheel when not required. The rolls are driven from enclosed pinions having fine pitch double helical teeth in enclosed housing, these in turn being driven from the motor by reduction gearing, also having double helical teeth, and enclosed in a cast-iron gearbox. A pump is also fitted which supplies oil sprays to the gear teeth. The gear-wheels are pressed hydraulically on to their respective shafts to ensure exact truth and consequently quiet running, these shafts being carried in bearings of the roller type, and the motor is connected to the pinion-shaft through a flexible coupling. With this design the frictional losses in gearing, bearings, etc., are reduced to a minimum, and the electric control is so efficient that with the rolls running in one direction they may be stopped and restarted to full speed in the opposite direction in a few seconds. The main driving motor is rated at about 120 h.p., with overload capacity to deal with the momentary peaks during the heaviest reductions on the thick slabs.

Mills of this type are similar to those supplied for finishing comparatively thick and wide aluminium strip.

After the metal has been reduced in the mill described above to thicknesses varying from 0·020 in. to 0·030 in. thick, depending on finished thickness of foil required, it is rolled to foil 0·001 in. to 0·003 in. thick in one pass through mill illustrated by Fig. 7.

The run of the metal through this mill is exactly the same as that shown by Fig. 3, and the mill itself is generally similar to that illustrated by Fig. 2, with the addition of new and improved features. The rolls are about 10¼ in. diameter, 30 in. face width, internally water cooled, and are carried in bearings also with interior water circulation for cooling. The unwinding mechanism at entry side of rolls, and the coiling gear at exit, is to the same substantial and new design as is adopted for the breaking-down mill, Fig. 6, the spools being interchangeable between the two mills. Feed rolls of hardened steel are gear-driven from the bottom mill roll, through machine-cut steel and phosphor-bronze spur-gears, change-wheels being supplied to give three or more ratios between the surface speeds of the main and feed rolls.

Fig. 6.—Breaking-down mill for rapid reduction of heavy slabs of lead.



* *Continued from page 143.*

The unique features in the design, apart from the coiling gear, are chiefly in connection with the driving of the rolls. The pinions and speed-reduction gearing are enclosed in one main cast-iron gearbox, with shafts running in roller bearings. All gears have specially accurate machine-cut double helical teeth, and spray-oil lubrication of teeth is provided from a chain-driven oil pump. The couplings

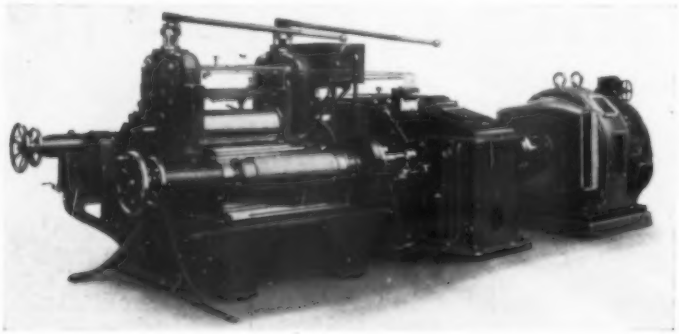


Fig. 7. Finishing mill for lead foil.

between driving gear and rolls are of a special universal type, in place of the ordinary spindle and muff couplings. These new couplings allow for maximum possible variations in roll centre distance, and give at the same time a perfectly smooth and regular turning effect. The bedplate and main frame of the mill is exceptionally rigid and substantial; this, together with the improved driving gear and couplings, eliminates all vibration, and perfectly smooth operation of the rolls on the metal is ensured. As will be understood, for successful rolling of a soft lead foil, 26 in. wide, 0·001 in. thick, at the high speed at which this mill is capable of working, it is essential that the rolls should have a perfectly regular action, and that vibration should be reduced to a minimum.

Tests on a mill of this type recently constructed prove that these requirements have been fulfilled. The mill was practically noiseless, even when working at the maximum speed of 120 ft. per min., and although during preliminary workshop trials the mill was only temporarily bolted down, a penny placed on the top of the gearbox *standing on its edge*, remained in that position without falling over on its side during the working of the mill on load.

The motor, connected to gearing by a flexible coupling, is of a special type, gives a variable speed under direct control of the operator, so that the rolling speed may be varied from 40 ft. to 120 ft. per min. A push-button switch operating automatic contactor switches is mounted on the mill frame, and has four buttons: "Start," "Raise," "Lower," and "Stop." When the "Start" button is pressed the motor is automatically started to run at its lowest speed. When all necessary adjustments are made to rolls, etc., and the foil is being delivered on to coiler in good condition, the "Raise" button may be pressed,

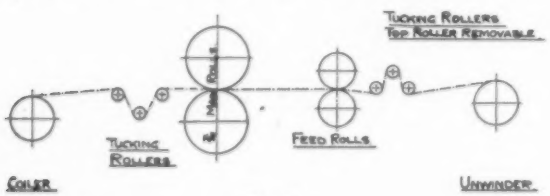


Fig. 3.

and as long as it is held to make contact, the speed of motor, and consequently of the rolls, automatically increases to the most economical speed for the particular work in progress. When the desired maximum speed is reached, the "Raise" button is released and the motor will continue to run at this speed as long as required. If by any chance it is found to be desirable to reduce speed, the "Lower" button is pressed and held, causing the automatic reduction of the speed until this button is released. To stop the motor, the "Stop" button is actuated, causing immediate stoppage of rolling, and the switch gear automatically puts the motor back to its lowest speed. It is considered that this control of the mill is as perfect as is possible to obtain. The friction clutch usually fitted to older mills is eliminated, and instantaneous control of rolls and regulation of speed to suit working conditions is obtained. Messrs. Robertson and Co., Ltd., are applying this same system to their latest strip mills for aluminium, brass, and other metals.

It should be mentioned that the main roll bearings are automatically lubricated by mechanical sight-feed lubricator, and a complete system of roll lubrication with upper and lower tanks, and circulating pump, is incorporated in the design.

One mill of the type here described is capable of producing 4,000 lb. to 5,000 lb. of 0·001 in. thick foil in 8 hours. It is interesting to note the advance made in regard to the rolling of foil at high speeds. Usually, tin and lead foil mills have rarely operated at speeds exceeding 45 ft. per min., and the highest speed for finishing mills usually adopted has been about 65 ft. per min.; breaking-down rolls rarely work at more than this speed. Compared with this, the modern breaking-down mill can be successfully operated at 100 ft. per min., and, as mentioned above, finishing-mill speeds have increased to 120 ft. per min.

Quite apart from the detail design of the plant employed for foil rolling, this branch of cold rolling of metal is undoubtedly the most delicate, and requires the very highest class of workmanship in the construction of the mills, and in the accurate grinding of the rolls. Moreover, tin-foil of such a fine thickness as 0·00025 in. is the thinnest product of the cold rolling mill. Pure gold, as required in the manufacture of gold leaf, is also rolled to an extremely fine gauge, and continuous coils of this precious metal in, of course, a narrower width, are rolled to a thickness of 0·00075 in.

The Phase-Theory Basis of Ageing Duralumin.

(*Continued from page* 180.)

x_2 to the branch $c_0' c_1'$, and x_3 to the branch $c_0'' c_1''$. In Fig. 16 the point of intersection a' (and also two other possible points in $c_0' c_1'$) with the saturation curve for B is labile throughout, and is therefore of no importance. In the point a'', however, two metastable branches of the saturation curves intersect each other. In the area around this point the solid solution will, therefore, be constrained to attain the composition of the metastable doubly saturated point a''_1, either by separation or solution, until splitting up of the solid solution or other change offers the possibility of its again reaching the stable doubly saturated point a.

The diversity of the reactions in the miscibility gap is still by no means exhausted. Different shapes and positions of the gap are possible, and the saturation curves may have even more complicated forms. The section of a saturation curve with a miscibility gap at the critical point has not been dealt with. Despite this incompleteness it has at least been shown how this kind of reaction can be handled.

Summary.

It has been shown that for the course of the separation of two crystal types from a super-saturated solid solution those with unstable saturation surfaces are determinative.

The course taken by a solid solution during the separation is dealt with, certain assumptions being made for the sake of simplicity, and three fundamental cases are discussed. In particular, the conditions in which the solution of a crystal type is possible are described.

A few special cases, which are of particular importance in the hardening of alloy steels are briefly discussed.

The Modern Blast Furnace and its Operation

By R. A. Hacking, M.Sc.

Part VI. Chemical Principles.*

Rate of Change of Composition under Counter-current Conditions—(b) The Descending Solids; Carbon Deposition at Low Temperatures; Reduction and Carburisation by Deposited Carbon at Higher Temperatures; Practical Considerations; Re-oxidation in the Combustion Zone.

WHEN the expression evolved by Korevaar—

$$\frac{dx}{ds} = K \frac{\text{Reaction velocity}}{\text{Velocity of reactant}}$$

is applied to the case of the descending solids, it will be seen that since the "solid velocity" is very low, the rate of change of composition—*i.e.*, the speed of reduction—with distance may be appreciable even when the reaction velocity is small. Taking into account the relative positions of the equilibrium and of the gas composition curves, reduction of iron oxides would thus be expected to commence virtually at the source of the downward current—*i.e.*, soon after leaving the stock line. Such is found to be the case. Mathesius (*Grundlagen*, 1916) states that reduction of Fe_2O_3 becomes perceptible below 400° F., and the reaction proceeds more rapidly with the progressive rise in temperature incidental to the downward travel of the charge. This observation has since been confirmed by other workers. In regard to the "reduction reactions," the progressive lowering of the oxygen content of the ore is probably more than compensated by the higher CO/CO_2 ratio of the gases met at each successive stage of the descent.

Carbon Deposition at Low Temperatures.

At low temperatures the gas composition curve G (Fig. 6) lies inside the field of "CO instability," at a considerable distance from the $C/CO/CO_2$ equilibrium curve (6). The partially reduced ore acts as a powerful catalyst in promoting the breakdown of CO, and "carbon deposition" occurs to an increasing extent as the temperature rises, until at 850° F. it attains a maximum. Bone, Reeve and Saunders (*J.I.S.I.*, 1930, I.) have demonstrated the magnitude of this effect at the above "optimum" temperature, and have shown that deposition occurs not only by envelopment, but by actual impregnation and disintegration of the ore pieces. Further, their experimental results show that in addition to metallic iron, Fe_3O_4, FeO and even finely-divided carbon can act as contact materials at these temperatures. They state that at the "optimum" temperature (850° F.) the reaction

$$2CO \longrightarrow C + CO_2$$

predominates over all the "oxide reactions." Above this temperature, the rapid decrease in the "distance potential" arising from the sharp rise of the $C/CO/CO_2$ equilibrium curve, causes a progressive falling-off in the amount of "carbon deposition," until at the point of intersection of the curves G and (6)—that is, at a temperature of about 1,300° F. in the case under review—this reaction is at rest.

During the same rise of temperature and beyond it, the "oxide reactions" are accelerating, so that the ore pieces enter the field of "CO stability" partially reduced, and enveloped and impregnated with finely-divided carbon. The stage of reduction, envelopment and impregnation attained naturally depends upon the nature and extent of the reacting surfaces, which in turn depend upon the composition, mineralogical form, preliminary treatment, size, and porosity of the ore pieces.

* *Continued from the November issue, page 28.*

So far as interaction between ascending gases and descending solids is concerned, it is evident that in average practice many of the reactions which produce CO_2 occur to a greater or less extent at the high temperatures within the field of "CO stability." Under this head fall:—

1. The reduction of that portion of the iron oxides which has persisted into this zone.
2. The "carbide reactions."
3. The reduction of MnO, SiO_2, P_2O_5, etc., by CO.

Reference has already been made to the very high velocity of the reaction—

$$C + CO_2 \longrightarrow 2CO$$

at temperatures over about 1,800° F. Thus, any CO_2 produced by any of the above reactions at temperatures of this order is unstable, and is speedily involved in interaction with solid carbon.

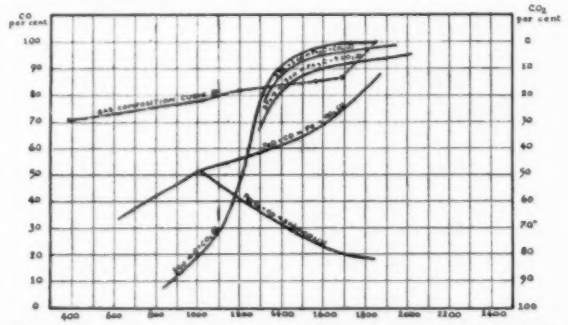


Fig. 6.—Temperature/Gas Composition Diagram for Blast-furnace Conditions. ($CO + CO_2$ considered as 100%.)

Taking as an example the principal "oxide reaction" concerned, the following two-reaction path is involved at high temperatures:—

$$FeO + CO \longrightarrow Fe + CO_2$$
$$C + CO_2 \longrightarrow 2CO$$

which, in the aggregate, amount to the single reaction which expresses the old conception of "direct reduction."

$$FeO + C \longrightarrow Fe + CO$$

Three sources of carbon are available for attack in this regard, viz.:—

(*a*) The carbon of the coke.

(*b*) The finely-divided carbon "enveloping" the ore pieces.

(*c*) The finely-divided carbon "impregnating" the ore pieces.

From the respective states of aggregation, and opportunity for contact afforded by the three forms of carbon available, it appears logical to assume that (*b*) is the first and (*a*) the second source of solid carbon involved in interaction with CO_2 in the zone of "CO stability." The terms "first" and "second" refer broadly to the sequence in which attack occurs as the charge descends and the temperature rises. On account of the much greater intimacy and extent of the "solid contact" and the relative isolation from the gas stream, the third source—the finely-divided carbon "impregnating" the partially-reduced ore—is more

likely to be involved principally in reactions which are discussed later.

In addition to the CO_2 evolved by the oxide and the carbide reactions, there has to be taken into account the considerable amount arising from the dissociation of the $CaCO_3$ (and possibly $MgCO_3$) of the flux. As previously stated, it appears that this source is chiefly responsible for the sudden appearance and rapid rise in the CO_2 content of the gas stream at temperatures of the order of 1,800° to 1,300° F., in which range the dissociation pressure curve of $CaCO_3$ is very steep.

Reduction and Carburisation by Deposited Carbon at Higher Temperatures.

A second important effect which is not indicated in the diagram (Fig. 6) has to be taken into account in studying the changes in composition of the descending solids.

During recent years it has been demonstrated that the finely-divided carbon deposited at low temperatures has a strongly reducing effect upon iron oxides at higher temperatures. Bone and his collaborators state that the carbon "impregnating" the ore pieces is the more important in this respect, the results of their laboratory-scale experiments indicating that at 1,382° F. (750° C.) it is more effective in reducing FeO than is carbon monoxide. This must be attributed primarily to :—

(*a*) The very fine texture of the form of carbon concerned.
(*b*) The large area of the reacting surfaces ; and
(*c*) The very intimate contact of the two reactants.

In the case of the carbon "enveloping" the ore, items (*b*) and (*c*) are lowered sufficiently to render it somewhat less effective than CO in reducing iron oxides at temperatures of this order.

Whilst the experimental conditions employed would appear to magnify the impregnating and subsequent reducing power of the carbon, there is no doubt that these phenomena are of considerable importance in actual practice. As a result of experiments on five charcoal blast furnaces, and investigations on a laboratory scale, Wüst (*J.I.S.I.*, 1927, II.) has come to the conclusion that the reducing and carburising effect of the deposited carbon extends at higher temperatures to the oxides of manganese, silicon, phosphorus, etc.

Practical Considerations.

In the above discussion of the problem, fairly definite functions have been ascribed to the three forms of carbon concerned, for the purpose of simplicity. In applying the conclusions to actual practice, the distinctions are not to be taken as definite, but rather that considerable mutual encroachment occurs.

The question arises as to the relative magnitudes, in actual practice, of the two methods of reduction and carburisation of iron and other oxides in the field of "CO stability"—viz., "gaseous reduction" by the two-reaction path, on the one hand, and "direct reduction" by solid carbon on the other.

No full-scale blast furnace has ever been worked without showing a considerable loss of the carbon of the coke (other than that allotted for carburising the iron) by "solution." In other words, the weight of carbon oxidised to CO at the tuyères is considerably smaller than the total amount charged per ton of pig iron. This effect is referred to in more definite terms later in the series.

It is hardly conceivable that the carbon of the coke should be attacked to any considerable extent before, or even as readily as the finely-divided precipitated carbon, either directly by the oxides, or by the CO_2 produced by the action of CO in forming metal or carbide.

Thus, whilst deposited carbon undoubtedly plays an important part in reducing and carburising iron, and providing a source of carbon for reaction with CO_2 in the zone of "CO stability," it is evident that it does not by any means supply the whole demand of this zone for solid carbon as a direct or indirect reducing and carburising agent. In other words, at the stage where all the carbon impregnating and enveloping the ore has been exhausted by oxidation (by solid or gaseous oxides), an appreciable amount of reduction and carburisation is still to be effected.

On account of the few points of contact between solid bodies of relatively coarse texture, it is probable that the two-reaction path is the one chiefly concerned in "solution loss" of the carbon of the coke, the gas phase acting primarily as an intermediary between the two solid phases. When the fusion zone is reached the proportion of direct interaction probably increases, since contact between a solid and a liquid phase is then involved.

Although there is no doubt that, given the opportunity, deposited carbon readily reduces the oxides of silicon, manganese and phosphorus to the metallic state, it is doubtful whether it can persist in actual practice to the high temperatures at which these reactions predominate.

From the respective degrees of concentration of, and opportunities for contact offered by, the oxides of the principal elements concerned in the modern pig-iron blast furnace, it appears logical to assume that reduction is effected in approximate sequence of rising heat of formation per pound of oxygen. These values are indicated in Table 4. In some cases the sequence is disturbed by the formation of oxide compounds, such as silicates, phosphates, etc.

Thus, it appears that the greater portion of the reduction and carburisation of manganese, silicon, and phosphorus lies in that portion of the work which is left directly or indirectly to the carbon of the coke. This conclusion is supported by the observed effect of these elements upon the amount of "solution loss" which occurs in actual practice. An extreme example is provided by the ferro-manganese blast furnace. It must not be supposed, however, that the connection is a simple one, as so many other factors influence the result.

Re-oxidation in the "Combustion Zone."

It is fairly well established that in normal practice, reduction and carburisation are complete some short distance above the tuyère level. In the inner cone of the "combustion zone" opposite each tuyère, strongly oxidising conditions are suddenly encountered, and a considerable amount of oxidation of iron, silicon, manganese, phosphorus, etc., occurs. Wüst has estimated

TABLE 4.
HEATS OF FORMATION OF OXIDES.
(In British Thermal Units.)

Oxide.	Per Lb. Molecule.	Per Lb. of Metal.	Per Lb. of Oxygen.	Per Lb. of Oxide.
MgO	258,120	10,755	16,132	6,453
BaO	240,120	1,753	15,008	1,569
CaO	236,700	5,918	14,794	4,227
Al_2O_3	706,680	13,086	14,722	6,928
V_2O_3	635,760	6,233	13,245	4,238
TiO_2	393,120	8,190	12,285	4,914
Na_2O	180,720	3,929	11,295	2,915
K_2O	176,760	2,266	11,048	1,880
SiO_2	352,800	12,600	11,025	5,880
MnO	163,620	2,975	10,226	2,304
V_2O_5	804,600	7,888	10,058	4,421
ZnO	152,640	2,349	9,540	1,884
Mn_3O_4 ...	590,400	3,578	9,225	2,578
Cr_2O_3	439,020	4,221	9,146	2,888
P_2O_5	657,540	10,606	8,219	4,631
SnO_2	254,340	2,146	7,948	1,690
H_2O (liq.)	124,200	62,100	7,763	6,900
C—O ..	122,472	10,206	7,655	2,783
Fe_3O_4	487,440	2,902	7,616	2,101
FeO	118,260	2,112	7,391	1,643
Fe_2O_3	352,080	3,143	7,335	2,201
MnO_2	225,540	4,100	7,048	2,592
H_2O (gas)	104,508	52,254	6,532	5,806
C—O_2	174,960	14,580	5,468	3,976
CuO	67,860	1,067	4,241	854
C—O	52,488	4,374	3,281	1,875

(*Continued on page* 196.)

The British Industries Fair*

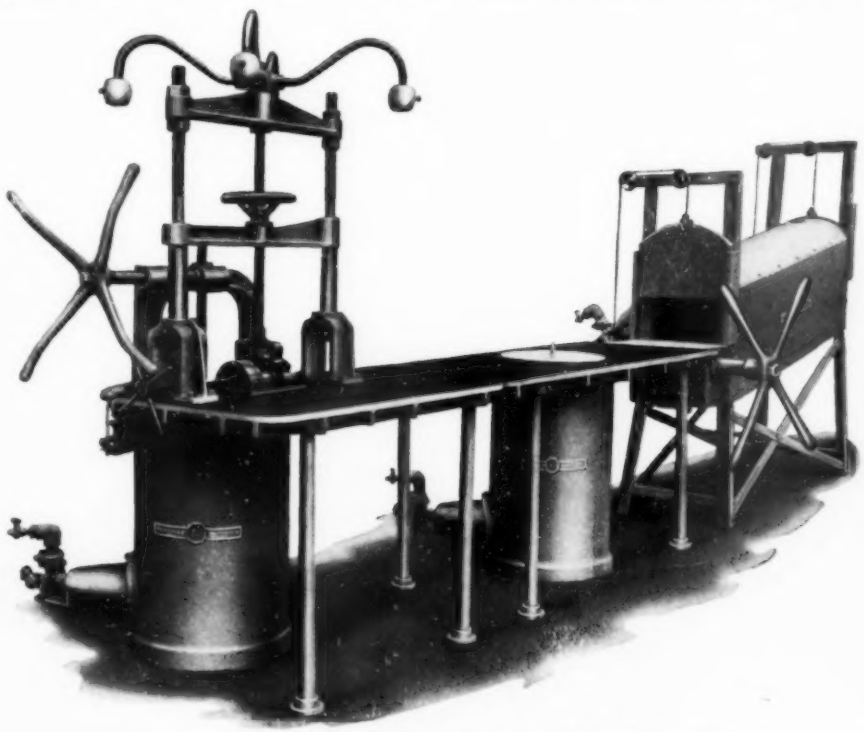
Exhibitors Regard it as a Valuable Incentive to Trade.

Among the many outstanding features exhibited none were more important than those resulting from progress in metallurgical science. It has provided data which enable the architect and engineer to use materials peculiarly suited to exacting modern conditions.

THE general satisfaction among exhibitors at the volume of business transacted as a result of the Exhibition is a clear indication of the success of this national effort. Although some firms have reported having done less business than at last year's Fair, particularly in exports, many have reported increased orders, and inquiries have been considerable. Probably the greatest advantage of an Exhibition of this character is the opportunity it affords of making new business connections which may lead to substantial orders in the future. Many possible buyers visited the Fair for new ideas, with a view to the improvement of their own products, so that when the opportunity occurs to modify a process, employ better material, or introduce new plant, information is available which is likely to enable them to requisition what they need. Thus, it is impossible to determine how much business is directly traceable to the Fair, the results of which are far-reaching, and may be spread over a considerable time. Some indication of the influence exercised may be gathered from the numbers who visited the Exhibition, given in the official estimate, which states that the number approached 150,000. Last year the number of home and overseas buyers was 96,000. This year the home buyers are stated to be 104,830, and the overseas buyers at just on 2,000, the balance being made up of the general public.

It is interesting to note that exhibitors generally regard the Fair as a valuable incentive to trade. This is emphasised by the desire of exhibitors to participate in next year's effort; many, in fact, intimated that increased accommodation will be required, and it is already apparent that increased space will be necessary for the next Fair, necessitating extensions of the buildings.

Probably the most outstanding feature exhibited was that due to metallurgical science. It has revolutionised the application of alloys to modern construction. It has provided reliable data which enable the architect and designer to use materials peculiarly suited to the physical conditions imposed by the conditions of modern life—materials resistant to fatigue under great physical stress, and resistant to corrosion. The metal industry of Great Britain was well represented at Olympia, but more particularly at Birmingham. No greater progress has been made in metallurgy than corrosion-resisting and stainless steels. These are invaluable in the domestic world in their application to cutlery, and in certain forms of engineering, such as turbine blades, pump parts, etc. The exhibits in this section displayed material with super-corrosion resisting properties, malleability and ductility, with a surface condition contributing to permanence, strength, beauty, and utility. Of this material, the architect and engineer are now able to take advantage for resisting the ravages of time, atmospheric and sea-water conditions, as well as corrosive fluids. The strength and durability of alloys of this kind render them efficient for constructional purposes.



Standard Plant for Whitemetalling Railway-type Axle-box Bearings, by Armstrong Whitworth.

In the form of sheet, bar, wire, rod, tube, casting and forging these alloys play an important part in the manufacture of an infinite variety of domestic appliances, for cooking, brewing, etc. To a large extent they have revolutionised the kitchen, with its hygienic and unbreakable sinks, counters, and pans of every description; but they have done more, they have opened out new possibilities in the engineering world, and have ensured economy as a result of increased service; particularly is this true of the heat-resisting alloys. In addition to exhibits referred to in our last issue, those of Messrs. Darwin, Ltd., included a complete range of "Pireks" heat and acid-resisting alloys and tool steels at Olympia and Birmingham. This firm was one of the first to make heat-resisting castings. The exhibit included two heat-treatment boxes exactly as they came from the furnace after their last heat, and after having been in use for many thousands of hours; both were quite free from scale, and showed the original cast surface quite clearly. Among tool steels this firm exhibited a range of qualities containing cobalt, another metal of which they are among the pioneer users.

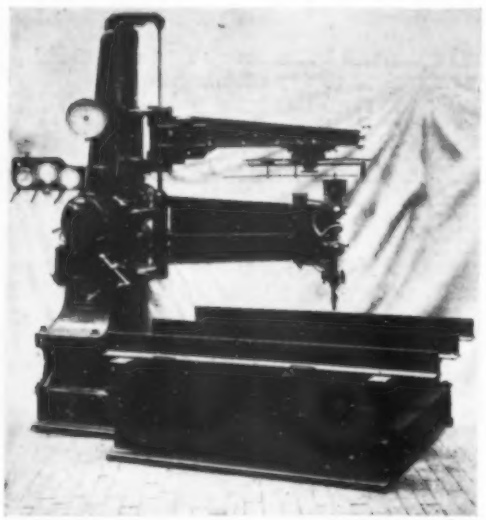
New Casehardening Steel.

A new "free-cutting" casehardening steel, taking a deeper case than carbon case-hardening steels, whilst

*Continued from page 126.

having excellent free-cutting qualities, was exhibited by the United Steel Companies. It is known as "Mancase," and is one of the Fox "Stocksbridge" alloy steels. It has been developed for high-speed production on automatic machines, followed by casehardening. After hardening, the steel takes a deeper case than the ordinary carbon case-hardening steels, and has a somewhat finer structure for both case and core.

Actual tests of "Mancase" on $1\frac{1}{8}$ in. bar, normalised at



A 55-in. Universal Oxygen Cutting Machine by Allen-Liversidge, Ltd.

900° C. and carburised at 900° C. and quenched, gave the following results :—

Condition	Maximum Stress, Tons Sq. In.	Yield Point, Tons Sq. In.	Elongation % on 2 in.	Reduction of Area.	Izod Value, Ft. Lb.
Normalised	31·8	21·8	36·5	64	85
Carburised	42·7	27	30·5	52	70

Further progress was noticeable in the production of non-ferrous alloys for special purposes. The number of important alloys of nickel continues to increase. In addition to the modern nickel-chromium stainless steels, a non-corrosive alloy of rich nickel copper, silver in colour, is also worthy of special notice. Interesting developments are to be noted in aluminium, bronze, and copper alloys.

Heat-resisting Electrical Alloys.

The heat-resisting electrical alloys made by the Telegraph Construction and Maintenance Co., Ltd., known as "Pyromic," come under this category. These are produced in three grades. No. 1, which is characterised by great strength at elevated temperatures and long life at temperatures of the order of 1,150° C.—1,200° C, is a patented ternary alloy, the base of which is nickel-chromium. No. 2 is a binary alloy of 80% nickel and 20% chromium, for use up to temperatures of 1,150° C. ; it is claimed to be commercially free from carbon, iron, manganese, silicon, and aluminium. No. 3 is a Ni-Cr-Fe resistance alloy of the same quality of production, and is recommended for use where temperatures do not exceed 1,050° C.

These alloys may be forged, rolled, or drawn with the greatest of ease, and are obtainable as rod, wire, and strip (up to 6 in. wide), or as castings.

This firm has also developed an alloy of iron and aluminium to withstand service in highly corrosive atmospheres at elevated temperatures, and also for use as electrical-resistance elements. Known as "Feralloy," this alloy is by constitution a single solid solution, which is perfectly homogeneous in structure. It can be forged, rolled, drawn into wire of any gauge, and welded, with the aid of fluxed electrodes, while machining is readily accomplished with modern tool steels.

Further alloys exhibited by this progressive company were "Mumetal," "Rhometal," and "Radiometal," which are the result of prolonged research for electrical purposes. Mumetal No. 6 is the latest result of British research into the magnetic properties of metals, and has now superseded all previous Mumetals. It has remarkable magnetic properties, which are well illustrated by the following comparison with the soft and permeable magnetic material, silicon-iron :—

	Mumetal.	Silicon Iron.
Initial permeability	20,000	500
Maximum permeability	100,000	7,000
Field for μmax	0·025–0·040 gauss	0·75–1·0 gauss
Hysteresis loss ergs/cc/cycle for B max = 5,000	36–50 ergs	500–1,000 ergs
Coercive force	0·06 gauss (B max = 5,000)	0·6 gauss
Remanence	4,000–5,000 lines	8,000–9,000 lines

The following particulars appertaining to these alloys will be of interest :—

	Mumetal.	Rhometal.	Radiometal.
Density	8·61 grms. per c.c.	8·2 grms. per c.c.	8·26 grms. per c.c.
Ultimate strength	40 tons per sq. in.	35 tons per sq. in.	40 tons per sq. in.
Yield point	20 tons per sq. in.	20 tons per sq. in.	21 tons per sq. in.
Elongation	25% on 5 in.	22% on 5 in.	25% on 5 in.
Cold drawing properties	Equivalent to Erichsen standard for tin plate		
Electrical resistivity	45 microhms per c.c.	100 microhms per c.c.	40 microhms per c.c.
Magnetic permeability	Depends upon heat-treatment	Ranges from about 80 to 1,500, according to treatment	With small superimposed polarising fields 1,000–2,000

The hysteresis and eddy current losses of Rhometal are very low, while Radiometal is a recent development in nickel-iron audio-frequency transformer cores.

Non-ferrous Alloys.

Of outstanding interest in the non-ferrous section were the exhibits of the Delta Metal Co., Ltd. Alloys were exhibited for almost every conceivable purpose. This firm recognise the impossibility of combining in one single alloy all the physical and chemical properties best suited to a great variety of purposes, and supply, as the result of many years' experience and research, a series of different standard alloys varying in composition according to the requirements and the purposes for which each is more particularly adapted. Some of these mixtures are based upon the introduction and chemical combination of definite quantities of iron or other elements in copper-zinc alloys ; others are improvements on various long-known bronzes, gun-metal, Babbitt's metal, etc.

It is not possible to mention all the alloys exhibited by this firm, but of those produced by them none is more widely known than Delta Bronze No. 4. It takes an important place among special bronzes, which enter so largely into the construction of a wide variety of machinery and engineering appliances. It is specially adapted for such work by reason of its great strength, toughness, malleability, and uniformity of texture, together with its property of resisting the corrosive action of sea and mine water, chemicals, gases, etc. This alloy is made in various grades to suit particular purposes. Small quantities of other elements are introduced into the standard bronze during the alloying processes, and are either retained or partly or wholly eliminated after having produced the desired effect. These slight modifications are made to meet special requirements.

Parts cast from this alloy may be hammered cold, for it has the effect of greatly increasing strength, but when heated to about 1,000° F. it becomes very malleable. It is then in a semi-plastic state, in which it can be worked with no less facility than wrought iron, and be stamped, forged, or pressed to any extent required, which operations increase its strength by one-half without in any way impairing its other very valuable properties. In many cases the wrought material (forged, stamped, or pressed, as the case may be) is to be preferred to the cast metal,

not only on account of its greatly superior strength, but also because the former is free from defects such as blow-holes and the like, which cannot always be obviated in castings, and which are often not detected until much labour has been wasted on the part.

A considerable variety of extended shapes were displayed by the Delta Metal Co., Ltd., and also by Vickers-Armstrong, Ltd., who have concentrated on the manufacture of extruded hollow-bar, tubes, and sections during the last few years.

In the drop-forging industry, which is so closely allied to modern engineering—and particularly to aeroplane and motor-car production—the use of light-weight alloys, capable of withstanding exceptionally heavy strain, is rapidly growing. The fact that the grain follows the contour of the die impression gives the drop forging a great advantage in strength over castings or hammer forgings, in which the grain may often run in the direction giving least resistance to strain.

An interesting feature was the display of non-ferrous metals and alloys exhibited by Priestman, which included many of the recognised specifications in aluminium, brass, and copper alloys. The ever-increasing demand for these definite compositions indicates that founders and engineers appreciate the advantages of a known quantity when dealing with metals. It is of interest to note that all the alloys displayed by this firm are standardised.

Wire.

Comparatively few people have an adequate idea of the large part that wire plays in our national and domestic life. Its uses are manifold, for it is employed in the home and in the factory, in engineering shops and in the production of a variety of manufactured products. Wire goods in many metals and alloys, and in many gauges, for a thousand uses, were on view. Exhibits included examples of high-conductivity copper wire; mild steel wire; wire for the engineering trades; wire for the production of nails, pins and needles, screws and rivets, and silk, cotton, asbestos, and enamelled-covered wire.

Engineers' requirements for rivets and threaded screws, etc., are sometimes for ½ in. round wire, and instances occasionally arise where greater thickness is called for. The extreme size at the other end of the scale is wire of a 2,000th of an inch. This wire of remarkable fineness is drawn through a perforated diamond or other precious stone. Pure nickel wire and silver wire are made for electrical, surgical, and other scientific requirements.

Many firms specialise in the manufacture of a definite class of wire goods, and their number tends to increase. Some manufacturing houses cater specifically for the respective requirements of telegraphy, telephony, shipping, and for the engineering and electrical industries. Again, there are many manufacturers who, for the most part, produce goods of domestic and kindred utility, such as are handled by hardware distributors. The demands of "wireless" have given an impetus to the non-ferrous wire trades.

Wire ropes represent, of course, an important feature in modern factory equipment, and galvanised wire and steel wire are largely used for hawsers and rigging ropes and submarine cables. In the electrical trades the need of copper wire is considerable, and the cycle industry takes heavy consignments of hard-drawn steel wire for spokes.

Some outstanding displays of various kinds of wire were shown by Richard Johnson and Nephew, Ltd., Barker and Allen, Ltd., British Insulated Cables, Ltd., John Rigby and Sons, Ltd., Rylands Bros., Ltd., John Smith, Ltd., Telegraph Construction and Maintenance Co., Ltd., United Steel Co., Ltd., H. H. Vivian and Co., Ltd., and The Whitecross Co., Ltd.

Die-castings.

The production of various parts as die-castings has made great strides during recent years, not only in the strength and durability of the alloys used, but also in the accuracy and fine limits to which the castings can be marketed. The advantages associated with die-castings make them an attractive proposition when large quantities of a particular design are required. The accuracy, uniformity in regard to size and weight tolerances, are important factors, while machining may be greatly reduced or eliminated altogether by using castings produced in dies either by the pressure or gravity methods. In addition to excellent surfaces, die-castings are generally homogeneous, and have good physical qualities. Production is continuous, and the output is rapid, keeping costs low. Some excellent examples of die-castings produced by the gravity process were exhibited by Diecastings, Ltd., which included such castings as gear boxes, pistons, crank cases, clutch cones, brake plates and shoes, magneto bodies with pole-shoes cast in, hydraulic jack bodies, etc., brush holders, levers, and other parts, scale and weighing machine parts, spools for artificial-silk machines, vacuum cleaner parts, loud speaker frames for wireless, components for automatic welding machines, and many articles of everyday use.

Many castings are produced in alloys to customers' specifications, but this firm manufacture their own standard alloys from virgin metals, and make a speciality of L8, L11, L24, and silicon alloys to accepted specifications.

The Coventry Malleable and Aluminium, Ltd., have recently widened their activities to the supply of die-castings, and they exhibited a wide range of products.

Malleable-iron Castings.

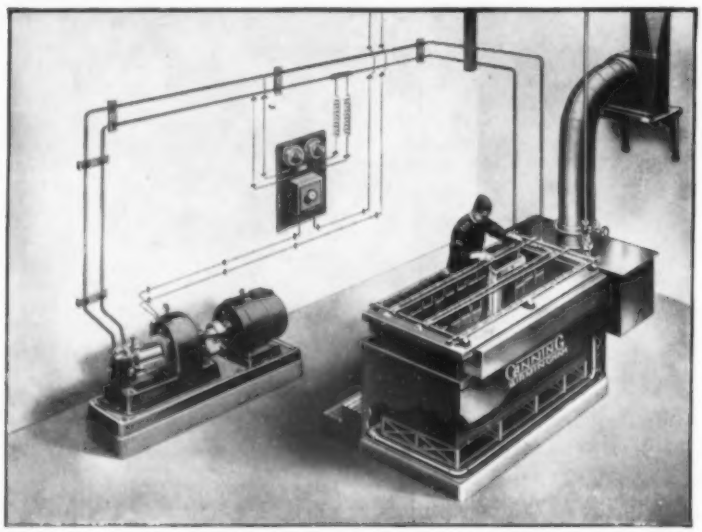
It is not long since many designers studiously avoided the use of malleable iron, owing to the unsavoury reputation which it had acquired in years gone by for having hard spots which interfered with machining, and being lacking in reliability. That this is not true nowadays is due to the results of much research, as well as accurate control and constant checking during production. The exhibits of Leys Malleable Castings Co., Ltd., and those of T. L. Hale (Tipton), Ltd., indicated very clearly the progress that has been effected. Each of these firms specialise in blackheart malleable iron, which differs from whiteheart considerably, the former retaining carbon within the metal in the form of small segregations of temper carbon. It is used extensively in the motor-car industry for important parts subject to shock and complex in shape.

Model Electrical Thermal Storage Scheme, by Reyrolle.

It is interesting to compare modern blackheart malleable, such as that instanced above, with the British Standard Specification for malleable cast iron. Leys Malleable Castings Co., Ltd., for instance, claim for their material a consistent attainment of 24 tons per sq. in., and an elongation of 15%, together with a bend test, using a British Standard test piece, of 170°—180°. These figures greatly exceed those of the British Standard itself, which fixes the minimum tensile strength at 20 tons per sq. in., the elongation at 7½% ,and the bend test at 90°. The

metal also has properties which make it valuable—in conjunction with its tensile strength and ductility—in electrical work, for not only has it a low hysteresis loss, but a very high magnetic permeability.

In addition to strength, ductility, and machining properties associated with the best type of blackheart, the



Chrome-plating Equipment.

castings of Messrs. T. L. Hale (Tipton), Ltd., possess rigidity not usually found in this class of material. This is considered to be a most valuable characteristic, and one which removes the only objection to the use of blackheart castings for important machine and constructional parts. Tensile strength usually runs from 22 tons to 25 tons per sq. in., with an elongation of 10/12% on a gauge length of 2 in. At these works the molten metal is produced in a duplex plant of the firm's design, in which one furnace is devoted entirely to melting while the second allows of adjustment of chemical composition, and ensures thorough mixing before casting into moulds. The furnaces are of the regenerative type, acid-lined, and are fired by purified producer gas. Metallic charges are accurately weighed and operations closely controlled by examination and analysis of metal and slags. Three of these duplex units have been erected, each with a capacity of 60 tons per day, and the usual procedure is to work two sets while the third is under repair.

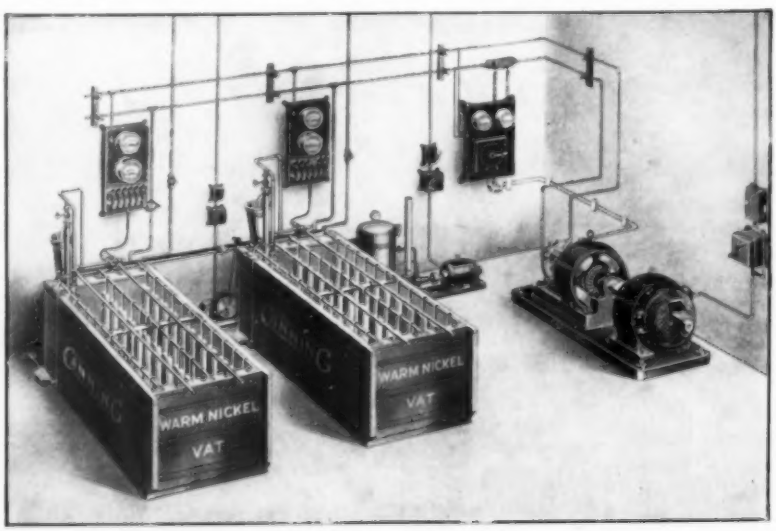
The heat-treatment of the white-iron castings is a most important operation, and demands the closest possible control. Prolonged heating and slow cooling are necessary in order to develop the best physical properties in the finished casting. The annealing ovens of Messrs. T. L. Hale have capacities ranging from 28 to 32 tons, exclusive of boxes and packing medium. They are heated by clean producer gas, and air for combustion is preheated before entering the ovens. The gas for each burner is measured, and is controlled by separate valves, and these, together with air and draught regulators, are all brought to one point on each oven. Temperatures are measured by thermo-electrical and optical pyrometers, and a predetermined time and temperature cycle is rigidly adhered to. The packing medium is practically neutral, and is present only to prevent distortion of the castings and to protect them from furnace gases.

Chrome and Nickel Plating.

Plating processes have made remarkable progress during recent years, particularly chrome plating, which has spread throughout the world at great speed, and now is to be met with in every land. The reasons for the rapidity with which the process has found favour, and the causes of its great popularity, are obvious when the advantages of chrome plating are considered. It gives a truly stainless deposit of mirror-like finish and extraordinary beauty, which will not tarnish; it does not require polishing, a wipe over with a damp cloth will remove any dust or dirt and restore its original appearance. The chrome deposit is extremely hard, and it is not attacked by alkalies or acids, with the exception of hydrochloric acid. An interesting display of modern plating equipment was exhibited by Messrs. W. Cannings and Co., Ltd., who made a feature of recording developments which have taken place in nickel plating. The chief of these was the new depolarised anodes, a new salt-spray test apparatus, and a new electric-coil heater for solutions.

It is now generally recognised that the purer the nickel anode the less likelihood is there of trouble with the working of the solution. The difficulty of pure nickel anodes becoming passive in solution has been overcome by the introduction of depolarised (depassive) anodes 99/100%. These are chemically pure nickel anodes which have been lightly oxidised in the process of manufacture, so that the tendency to passivity has been entirely eliminated. Under no circumstances do these anodes form a black skin of nickel peroxide, but dissolve freely and readily in the solution.

These anodes are made of oval section, as it has been found that this shape is the best and most logical of all for nickel anodes, because the current distribution of an anode is greater at the edges than at the centre, and the oval shape provides the maximum surface which can be attacked by the electrolyte, allowing for easy replacement of the nickel as fast as it is taken by the cathode. Thus, the best surface is exposed to the action of the current, and the nickel is taken from the anode in exact



Nickel-plating Equipment.

quantitative balance to the metal which is being deposited.

The absence of black oxide keeps the solution extremely clean and entirely free from suspended particles, which is of paramount importance in permitting rapid nickel plating, as roughness and unevenness of deposit are eliminated.

Welding Equipment.

The supply of plant and electrodes to meet the requirements of the engineering trade is difficult and complicated because the requirements vary so much. The A.C. welder requires an easy-flowing electrode, the piece-rate worker wants a fast electrode, the boiler repairer wants one which will not cover him with showers of sparks when he is welding a combustion-chamber roof, and the odd-job man wants one which will weld anything from a broken casting to a gun-metal gear-wheel. The engineer of to-day makes use of a host of special steels and alloys; stainless steels and metal alloys for chemical plant, high-tensile steels for pressure vessels and pipe-lines, manganese steels for resistance to wear; and as every branch of engineering calls for welded design, each of these metals must have its special electrode and its special welding technique. Large-scale operations and mass-production methods call for the elimination of hand processes.

One of the most modern methods of welding consists in shielding the arc with gases which have no tendency to react with the weld metal. Such gases as hydrogen and the mixture of hydrogen and nitrogen produced by cracking ammonia have been successfully applied with remarkable results in the finished product. The exhibits of Murex Welding Processes, Ltd., were outstanding in this respect. While the British Insulated Cables, Ltd., displayed, among other equipment, a machine designed to weld fine gauges of copper wire down to 0·0124 in. dia. The wires to be welded are clamped in the machine in the usual manner, after which a swinging arm is released, the current applied by a small switch lever, and the weld is automatically made. Care is required to see that the two wires are in true alignment, otherwise sound welds cannot be produced.

The machine consists of a small single-phase alternating current transformer, the primary being wound for any of the usual supply voltages. There is a plug and flexible cord at the back of the machine, to which must be connected the adaptor or plug to suit customer's connection. On the front of the machine is a regulating switch with four positions. "Zero" is on open circuit, and "1," "2," and "3" are fast, medium, and slow speeds, respectively.

The clamps are mounted on the top of the machine, the one on the left-hand side being fixed to the base, and that on the right mounted on a swinging arm. This arm is kept in an open position by means of a small lever. This is capable of adjustment by means of a suitable screw. The movement of this screw in either direction opens or closes the gap between the two clamps.

On the top of the machine is a small operating switch, which is double-acting, the circuit being closed by hand, and opened by means of a knock-off rod attached to the swinging arm of the machine.

Research Apparatus and Equipment.

It was a happy idea to assemble the majority of the exhibits of metallurgical laboratory equipment in one section at Olympia. This method facilitated the examination of modern appliances, and it was made clear how various operations are able to be controlled with comparative ease. Progress in the examination of metals and alloys has been considerable. During recent years there has been a growing appreciation of the importance of the effects on the properties of alloys of constituents present in very small proportions. The increasing complexity of ferrous and non-ferrous alloys has greatly increased the difficulties of the metallurgist, who is often at a loss to determine, except after delays often running into several days, whether a certain important constituent (whether desirable or harmful) is present in a particular material. It is in such problems that the permanent adjustment quartz spectrographs introduced by the firm of Adam Hilger, Ltd., have been receiving more and more attention from metallurgists, until the position has been arrived at where those acquainted with the advantages of the spectrograph find it as indispensable in the metallurgical laboratory as is the micrograph.

It provides a simple, certain, and very speedy means for detecting the whole of the metallic constituents of any metal or alloy. A photographic record of the whole of the metallic ingredients of a specimen can be obtained in half an hour, and each of the various ingredients can be detected by examination of the photographic plate lasting about five minutes.

Aliminium in the Construction of Furniture.

Such has recent development been in the use of light metals for domestic and industrial applications that each branch is now almost an industry in itself. The use of aluminium and high aluminium alloys for the fabrication of furniture originated in France not much more than ten years ago, and since then has received considerable attention in America. In this country, however, it has been neglected, and it is only recently that furniture makers have begun to make use of the advantages offered by a metal that is light, strong, durable, clean, and incombustible, and, above all, easily workable. In America and on the Continent aluminium has been used for furniture in a form of high-strength corrosion-resistant alloy containing small percentages of silicon and magnesium. This alloy comes from the rolling mills in sheets, tubes, or other shapes, ready heat-treated. It is then die-formed in power presses, and the parts are assembled and joined together by autogeneous welding to form a very strong and rigid construction; the completed frames are again heat-treated to produce resistance to surface-denting, and then sand-blasted to remove oxides. Finally, they are sprayed with varnish and then enamelled.

Aluminium furniture is suitable for service anywhere, but more especially for office and hotel use. The rise in its popularity abroad makes it clear that there is very large scope for its extended use and for the establishment of a larger market for it in this country.

Welding by the "Premag" Process.

THE successful welding of copper depends on the following essential factors: (1) A base material and alloy filler-rod of suitable composition; (2) a suitable flux properly applied; and (3) correct technique and experience. Imperial Chemical Industries have now developed a type of copper eminently suitable for welding; while a suitable alloy filler-rod and flux for use with this special brand of copper can be obtained at reasonable prices. There are also a large number of smaller factors in welding technique, which, if neglected, all combine to prevent the success of the operation. Preparation of the metal, contraction allowances, insulation against heat losses, and proper flame adjustment are all small matters to which it is essential to pay attention. Copper has a high thermal conductivity; it is therefore necessary to use more heat in preheating than when welding mild steel. In applying the cleaning flux, care must be taken that every part of the metal to be welded is thoroughly covered before heating. The welding process differs a little according to the thickness of the metal to be welded, for in some thin sheets or plates very little filler metal is required. As in the case of other metals, copper welds are improved by hammering on both sides to break up the large grain structure in the parent metal caused by heating.

Murex Welding Processes, Ltd., have issued a booklet dealing with copper welding by the "Premag" process; it contains a short introduction referring to the general principles of this type of welding and further information regarding the actual technique involved. A great deal of research has been carried out in the effort to make this process more successful, but it is only recently that a method has been produced by which successful welds can be obtained with ordinary skilled labour.

"The Sulzer Technical Review for 1930" contains particulars of the Sulzer marine refrigerating plant fitted in the new motor liner, *Johan van Oldenbarnevelt*.

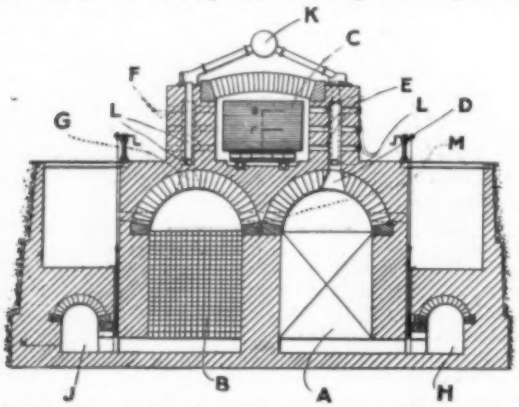
Other articles deal with new types of high-pressure steam traps, and with investigations made in connection with radiation of heat from the grate in a water-tube boiler. In addition, there are references to new orders for Diesel-electric locomotives, Diesel-electric rail cars, a 5,250 b.h.p. Diesel engine, an 11,000 b.h.p. Sulzer two-cycle Diesel engine, a novel floating Diesel-electric power-station, an irrigation plant, and a 530,000 cub. ft. waterless gasholder.

Some Recent Inventions.

A PROCESS FOR HEATING IN A REDUCING OR OXIDISING ATMOSPHERE.

IN industry it is often required to heat substances to relatively elevated temperatures in a reducing or oxidising atmosphere, or in the presence of a particular gas, either for the purpose of simply heating the substances or in order to obtain chemical reaction. In the metallurgical industry, for instance, particular pieces of metal are annealed for the purpose of softening them. In annealing furnaces in which the heating is effected by flames or by gaseous products of combustion, the pieces to be heated are exposed to the oxidising action of the flames. The combustion products contain large proportions of water vapour and carbonic anhydride which may have an oxidising action at high temperatures. Even if the combustion products also contain reducing gases the latter are diluted with such large proportions of neutral gases that their action is considerably diminished, if not nullified.

Recent improvements in a process of heating provides simple and economical methods of heating bodies or substances under the required oxidising, reducing, or other



conditions by placing the bodies or materials in a stream of gas heated in a regenerative system, whereby the hot gases employed to heat the bodies or materials may have any oxidising, reducing, or other chemical qualities.

In this method of heating a combustible gas or a supporter of combustion, which has been raised to a high temperature in one element of a reversible gas-heater, is passed through a chamber containing the materials or articles to be heated, after which it is mixed either with a supporter of combustion or a combustible gas, as the case may be, and burnt in the other element of the heater. The apparatus is illustrated in Fig. 1, and comprises chequer brickwork filled chambers, A, B connected on the one hand to the heating-chamber C, through passages D, E, F, and G, and on the other, to a reversing-valve through the flues H and J. The gas to be burnt with that which has passed through the heating-chamber is supplied from a main K, and is delivered through ports L to one or other of the chambers A, B, according to the phase of operation. By providing a connection M between the chambers A, B, hot gas which has not passed through the chamber C can be burnt in the chambers A, B, and by providing connections between the flues H, J, and the chambers A, B, respectively, cold gas can be supplied for combustion. The chambers A, B may be arranged in opposite sides, or both on the same side of the chamber C, and the waste gases from the heating system may be passed through a recuperator. In a modification, both gases are heated by reversible heaters, and in another modification, part only of the gas from the heaters A, B, is passed through the chamber C, while the remainder is burnt in an external flue. When the heating-chamber C is of the tunnel type, an end chamber may be provided for cooling the articles.

333,192. Herbert Schaefer of Luxemburg, patentee: F. E. Rogers, agent, 181, Queen Victoria Street, London, E.C. 4. August 1, 1930.

A HARDENING ALLOY FOR COPPER OR ITS ALLOYS.

EFFORTS have been made from time to time to devise some hardening medium for copper and its alloys, which would function as well as tin and improve the physical qualities of the alloy of which it formed a part. Such a medium has been developed, which consists of iron, silicon, and copper. It is used in conjunction with copper alloys of high copper contents, to which the hardening alloy is added.

The iron constituent of the hardening alloy may be obtained by alloying steel and cast iron, and the steel may include one or more of the metals—nickel, chromium, molybdenum, tungsten, and vanadium. The hardening alloy may also contain manganese or phosphorus or both; for example, it may consist of 10–30% of a steel-iron mixture, 10·70% of silicon, up to 15% of manganese, up to 10% of phosphorus, and the remainder copper. In the production of copper alloys containing zinc, all or part of the zinc may be included in the hardening alloy, or the zinc may be added to the copper or copper alloy independently of the hardening alloy. The normal tin or zinc content of bronzes or brasses may be wholly or partly replaced by the hardening alloy. A final alloy may, for example, consist of 88% of copper, 2% of zinc, and 10% of the hardening alloy. The alloys may be annealed by heating to over 800° C. and cooled quickly in water or oil, followed, in some cases, by reheating to not more than 450° C.

335,950. Messrs. Vickers-Armstrongs, Ltd., Vickers House, Broadway, Westminster, W. Machin, 37, Carlton Avenue, and W. B. O'B. Goudielock, 42, Fairfield Lane, both in Barrow-in-Furness, patentees.

COPPER AND NICKEL ORE TREATMENT.

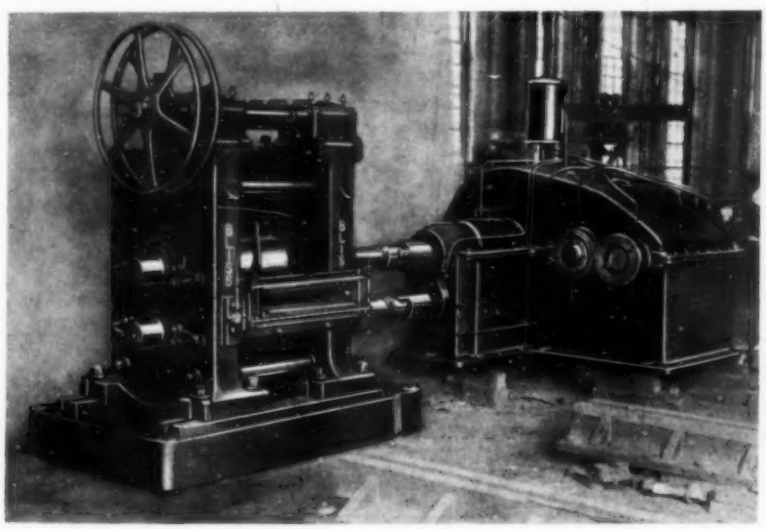
IN a recent improvement in the treatment of copper and nickel sulphates, chlorides, carbonates, and oxides, the ores, concentrates, etc., containing sulphides, or copper or nickel oxidised compounds, together with added sulphur, for instance, added iron sulphide, are treated with air or oxygen at 600° C. to convert the copper and nickel to sulphate, the charges not being disturbed or rabbled during the reaction. The heat of reaction is usually sufficient to maintain the necessary temperature when the reaction has once begun, and a thin layer of inert material may advantageously cover the surface of the charge. The addition to the charge of ferrous sulphate or chloride is advantageous when nickel is present, and these salts may replace added sulphide. Iron present mainly remains in the residue as oxide on leaching, together with sulphates of gangue constituents, such as calcium. Oxygen may be used to start and finish the reaction, and air or air enriched with oxygen to maintain it intermediately. The oxygen needed may be obtained partly by electrolysis of water, and partly from liquid air, and the hydrogen and nitrogen also obtained be combined to give ammonia, which may then be used, with or without carbonic acid, to precipitate copper and nickel from the sulphate solutions obtained, the resulting ammonium sulphate being recovered. The sulphur content of materials containing excess of sulphur may be reduced by a preliminary heat-treatment. In the treatment of copper-iron bearing mattes containing lead, lead sulphate formed remains in the residue. From the latter, precious metals, if present, may be recovered by the usual means. Apparatus for use in the process may comprise endless chains carrying trays or stacks of trays through lengthy heat-insulated tubes, but retorts, muffle furnaces, etc., may also be used. According to the first provisional specification, temperatures of 450 above 600° C. may be used, and an addition of ammonium, magnesium, or calcium chloride be made to the charge; according to the second, when upon lixiviation copper remains in the residue it may be extracted with acid. Reference is made to 338,556. E. A. Ashcroft, Waye House, near Ashburton, Devon, patentee. Specifications 12,305/11, 26,138/13, and 14,295/14.

Recent Developments in Tools and Equipment

FRASER AND CHALMERS' "BLISS" ROLLING MILLS.

THE Fraser and Chalmers Engineering Works of the General Electric Co., Ltd., are now manufacturing backed-up rolling mills of the four-high and cluster types to the designs of the E. W. Bliss Co. of Salem, Ohio. This American firm has had considerable experience in the manufacture of cold-rolling mills, and many important developments made in recent years are incorporated in the designs. These mills, being more in the nature of precision machines, are gradually replacing the standard two-high mill. They are used for hot and cold rolling sheet and strip steel and all non-ferrous metals, and have been successfully applied to hard and soft steels, monel metal, nickel, molybdenum, tungsten, brass, copper, aluminium, silver and white gold.

For light and medium work, two-high mills can be supplied, with white metal or roller bearings, but for heavy service, backed-up mills are used, either of the four-high or cluster type, roller bearings being employed in each case. The backed-up arrangement employing large diameter backing and supporting rolls and small working rolls makes it possible to obtain much higher rolling pressures, greater reduction, and lower power consumption than in the ordinary type of rolling mill; it is particularly suitable for cold rolling, and ensures a high degree of finish and a close-rolled product of even gauge.



The 18" × 22" Mill is of robust design.

Two-high Mills.—On account of its simplicity, the two-high mill is very suitable for the hot or cold rolling of metals of medium or narrow widths. Generally speaking, the width of material that can be rolled satisfactorily on two-high mills will be as follows: For gauges ranging from $\frac{3}{16}$ in. to 0·035 in., width = diameter of roll; gauges ranging from 0·035 in. to 0·015 in., width = half diameter of roll; gauges ranging from 0·015 in. to 0·005 in., width = one-third diameter of roll. For softer metals, such as lead, these widths can be increased in proportion to the softness of the material as compared to steel.

Journal bearings of brass or bronze are recommended where heavy reductions are required, but for light and medium work, such as is usually carried out in finishing mills, roller bearings are preferable. With journal bearings, the roll diameters available range from 8 in. to 20 in., with corresponding capacities of 175,000 lb. to 900,000 lb. pressure between the rolls. For larger widths, which would necessitate rolls of larger diameter, backed-up mills should be used. The bearing pressure on the necks is in all cases 2,000 lb. per sq. in. Heavy draughts naturally necessitate low speeds, the speeds on individual stands being about 60—120 ft. per min: for stands arranged in tandem, the speeds on the second stands will be increased to 75—150 ft. per min. Where the draughts are relatively light and the material is ductile, due to previous annealing, still higher speeds are used, the rolls giving a finishing pass to the material at speeds of 125—300 ft. per min.

With roller bearings on the two-high mills the capacities are less, so that larger sizes are necessary to perform the same duty on a given width of material. Smooth working is assured, the heat generated by neck friction is eliminated, and a saving of power of from 40—50% is effected.

The rolls are of chilled iron where the neck stress is not too great—*i.e.*, on journal bearing mills and on the larger sizes of roller-bearing mills. On the smaller roller-bearing mills they should be of hardened steel, due to the increased neck stress; if chilled-iron rolls are essential, a larger size of mill must be used. With existing journal-bearing mills it is practically impossible to fit roller bearings on the chilled iron necks, the limited space preventing the use of roller bearings big enough to carry the excessive pressures encountered.

The general design of Bliss two-high mills tends to produce an efficient and substantial machine. The robust design of the housings, the hand screw-down gear, and the cooling of the rolls (for cold rolling with journal bearings) are special features. The cooling is provided by a small hole in each roll, through which water is applied to the interior of the journal bearing; with roller bearings, cooling is, of course, dispensed with. The mills are ideally suited to cold rolling of medium and narrow widths, and are equally satisfactory with hot rolling.

Backed-up Mills.—Some general considerations, leading to the employment of backed-up mills for heavy duty, are of interest.

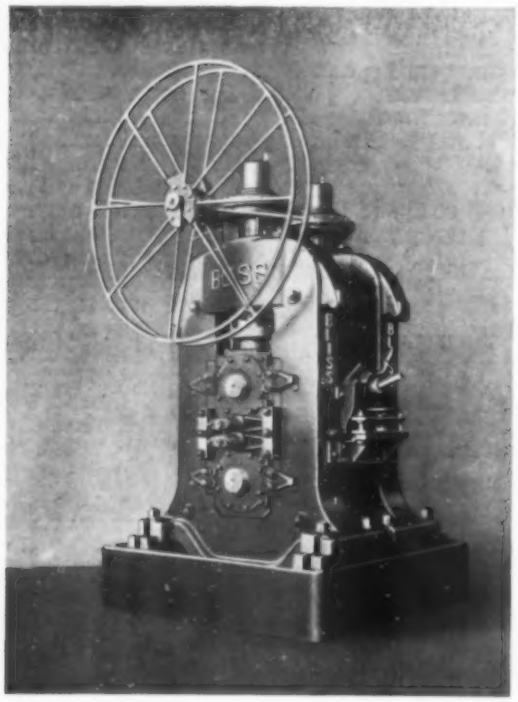
For hot strip, the ordinary rolling mills used in Great Britain are capable of rolling strip up to 20 in. wide; with thin gauge, anything wider entails loss of strength, greater power, and less tonnage output, and although hot strip has been rolled up to 36 in. wide it is not economical. Strip manufacturers are, therefore, limited to width, not by hot strip, but by cold strip.

For cold strip, the factor that limits the width that can be rolled, is the roll pressure. In two-high mills it has been seen that the diameter of the rolls increases in proportion to the width of the strip, but the arc of contact between the rolls also increases, and is equal to—

radius of roll × total reduction.

Taking, for example, cold low-carbon steel, the crushing strength is 70,000 lb. to 100,000 lb. per sq. in., and each pass increases it up to, say, 150,000 lb. per sq. in., according to the amount of reduction required, 40—60% total reduction being usually done in three or four passes. Taking the

crushing strength to be 120,000 lb. per sq. in., and the reduction to be 20% for each pass, the pressure on strip 10 in. wide by 0·1 in. thick between 10 in. diameter rolls works out at 380,000 lb., and with strip 50 in. wide on 40 in. diameter rolls, the pressure is 3,900,000 lb. Thus, for the same percentage reduction, increasing the width five times



$5\frac{1}{2}'' \times 19'' \times 18''$ "*Bliss*" *Four-high Mill.*

increases the pressure ten times, the pressure per inch of width being doubled. It will be seen from this that a reduction of 1 in. in strip from 10 in. to 50 in. wide would necessitate pressures of the order of 1,000,000 lb. to 4,000,000 lb. and rolls of 20—40 in. diameter, which is not practicable with two-high mills. Backed-up mills are specially designed for these conditions.

In backed-up mills the working rolls are of much reduced diameter, the large pressures being obtained by means of heavy backing and supporting rolls of greater diameter, which augment the pressure of the working rolls. Two types are made—"four-high" and "cluster." In the former, two backing rolls and two working rolls are used; in the latter, four backing rolls and two working rolls, giving a wider range and larger capacities.

In the "four-high" type the working roll diameters range from $4\frac{3}{4}$ in. to 16 in., and the capacities range from 254,000 lb. to 2,600,000 lb. In the "cluster" type the diameters range from $4\frac{1}{4}$ in. to $14\frac{3}{4}$ in., and the capacities range from 210,000 lb. to 3,300,000 lb. The largest size mill has rolls 55 in. long, and will deal with 48 in. stainless steel strip, the "cluster" type giving a 25% reduction in 7—8 passes for heavy sheet and 5—6 passes for light sheet.

The main advantages of the backed-up type of Bliss mill are:—

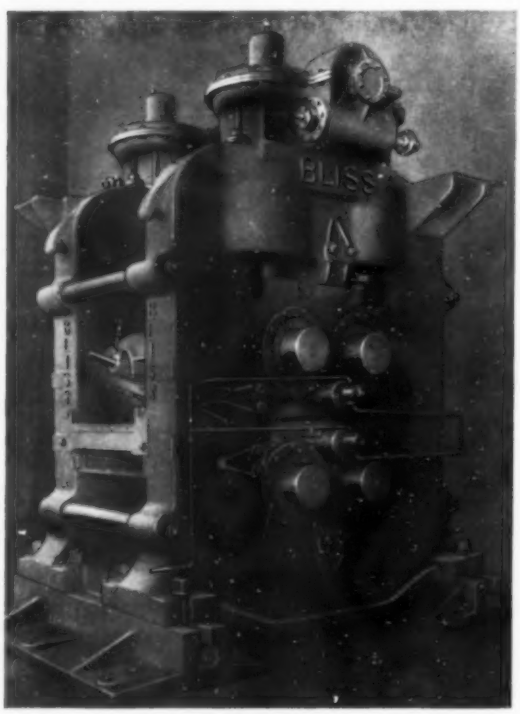
1. Increase in speed of rolling.
2. Increased reduction percentage—*i.e.*, fewer passes for a specified reduction.
3. Saving in power.
4. Use of small hard steel working rolls.

The reduced number of passes necessary is well exemplified in the case of a large steel company rolling cold nickel and monel metal sheets. With a two-high mill, it was found that with 26 in. diameter rolls on 36 in. wide strip, 50 to 80 passes were necessary to reduce the thickness by 35%, and that sledge hammers had to be used on the screw wrenches; the work was thus most laborious and expensive. With a backed-up Bliss mill of the four-high type the number of passes was decreased from 60 to 5. Similar results are obtained on hot rolling, leading to a large demand for these mills.

Backed-up mills are equipped with roller bearings in all cases, and give a 40—50% greater capacity than a two-high mill fitted with journal bearings working on the heavier draughts.

The use of small working rolls is an important point. With 20 in. wide material only 8 in. or 10 in. diameter working rolls are required on a backed-up mill, instead of 18 in. or 20 in. rolls in a two-high mill, thus effecting a considerable economy both in original cost and replacements. Also, for a given reduction, the smaller the roll diameter the less the hardening of the material—*e.g.*, a 50% reduction produced by a 10 in. diameter roll will result in material less brittle than if a 20 in. diameter roll were used; greater reductions are thus permissible, and as the material becomes wider and thinner, much greater pressure per inch of width is possible.

The working rolls for cold rolling are of nickel chrome steel (95—100 sclerescope); for hot rolling they are made of chilled cast iron. The backing and supporting rolls are made of chilled iron, alloy cast iron or cast steel, or forged steel. Chilled iron is used where the neck stresses are low, as it has a hard brittle surface, will hold its shape better than cast steel, and is obtainable at relatively low cost; its good wearing qualities allow at least 6—8 months' operation without removing for re-grinding. Alloy cast iron or cast steel are used where the neck stresses are heavier and give a strength about 30% greater than chilled iron. Forged steel is the best material for heavy stresses, but



"*Cluster*" *Mill.*

its high cost makes it economical for small and medium diameter rolls only.

No water cooling is required, as the roller bearings do not generate heat in the necks. Water is, however, often used as a cooling medium internally in the working rolls, according to the nature of the material being rolled and the draughts being taken. Much useful data has been obtained regarding these mills, which is available to those interested.

Business Notes and News

The New Cunarder.

THE interest of a large section of the engineering world has for some time been focussed on the building of the new Cunarder at the Clydebank yard of Messrs. John Brown and Co., Ltd., and announcements regarding the orders for equipment and appliances are eagerly awaited.

The British Thomson-Houston Co., Rugby, has received an order for seven turbo-generators for the ship's auxiliary services. Each of these sets, of which four are for use as "main machinery sets" and three as "hotel service sets," comprises a 10-stage turbine driving a direct-current generator through single-reduction gearing. These sets will have a combined capacity sufficient for the needs of a medium-sized town, for each will be rated at 1,300 kw. (normal), 225 volts. The "main machinery sets" are to supply power for the numerous auxiliaries such as pumps for water, lubricating and fuel oil, bilge and ballast, etc., while the "hotel service sets" will be used for heating, cooling, ventilation, lifts, lighting, and all the other services installed for the comfort of passengers and crew. As the service sets will be needed in port, as well as at sea, they will operate off auxiliary boilers supplying steam at the turbine stop-valve at 230 lb. per square inch guage, at a total temperature of 650° F. The "main machinery sets" will operate on steam at 370 lb. per square inch gauge at a total temperature of 680° F.

New Steelworks.

Preliminary work has been started on the erection at Ecclesfield of the new steelworks of Messrs. Hall and Pickles, of Manchester and Sheffield. It appears that the site for these works was acquired some time ago, but the building was postponed owing to trade depression. It is intended ultimately to erect works covering some ten acres, but at present activities are being confined to a small part of the site, where it is thought that electric furnaces will probably be erected. The site is conveniently situated by the side of the railway, to the north of Ecclesfield station.

An Industrial Film.

Those whose occupation brings them into touch with the various processes of grinding and finishing in the engineering world, will be interested to learn that the Carborundum Company, of Manchester, have revised their film:—"The Jewels of Industry," and it is now "on tour" in the Lancashire area, having already been shown to large and appreciative groups of engineers in Scotland and the North. This film deals with the story of the creation of Carborundum and Aloxite, from the early experiments made by Dr. Acheson, to the processes by which modern grinding-wheels of all conceivable shapes are made. Some interesting and spectacular views are included of the company's Canadian plant at work. Ships are seen carrying the raw Carborundum and Aloxite across the Atlantic to Manchester, where it is delivered direct into the sidings of the company's plant at Old Trafford. It concludes with a tour of some of the most important engineering workshops in Great Britain, where the grinding-wheels are seen at work.

F.B.I. Report on British Industry.

Measures to give British industry a new lease of life are suggested in a report on "Industry and the Nation," published by the Federation of British Industries. While asserting that continuous development and rationalisation of industry can only be achieved by spending money, the report makes it clear that before that money can be spent confidence must be restored. The methods suggested for this are: Widest possible inter-Imperial preference and industrial protection and reduction of taxation and other charges. The report stresses the importance of taking immediate emergency action.

Messrs. Thos. Firth and John Brown Ltd.

We have already drawn attention in a previous issue to the recent amalgamation of the two Sheffield firms of John Brown and Co. and Thos. Firth and Sons. It is now announced that a meeting is to be held with the intention of settling the name of the combine, which, it is understood, will in future be known as Thos. Firth and John Brown, Ltd. It is expected that the change will be effected before the end of the month.

British Steel.

For a long time the mark "B.S." on steel has been a source of inconvenience to buyers, especially to architects and others who specify British steel, but who do not know whether they are getting it or not. Foreign steel is often manufactured to British specifications, and to indicate that this is so, Continental manufacturers have been in the habit of marking their products "B.S." This merely signifies "British Standard" or British Specification, not, as the inexperienced suppose, "British Steel."

The news, therefore, that a national mark for steel has been adopted will be of interest, not only to those in the industry, but also to all whose work involves the use of steel for constructional purposes. In future, unless the distinctive mark "British Steel" is apparent, buyers will know that what they are looking at is neither of British workmanship nor of British quality. We say "of British quality," because the mark "B.S." has also led some people to suppose that, being made to British standards, the steel is of first-class quality. This is not so. The great bulk of Continental steel is manufactured by the Bessemer process, which was discarded long ago by British steel-makers; this is a process in which modifications cannot be made during the operation, and the product must simply be taken on its face value. On the other hand, the modern open-hearth process, as used by British steel-makers, allows for the testing of the quality of the steel while it is being made. The advantages of this process are obvious.

People sometimes insist that low-grade Bessemer steel serves its purpose adequately, and that the higher quality produced by British manufacturers is not needed. Surely, a stronger steel allows for a reduction in weight and size, and therefore reduction in price as well? It is true that the better quality steel is more expensive, but the additional expense is easily balanced by reductions in quantity.

Immediate results of the adoption of the new national mark are not, of course, expected, but it is hoped that it will serve to remind the world of the high quality of British goods, and lead to an increase in the production figures of home manufacturers.

Oil from Coal.

Many spheres of industry are dealt with in the report of the Department of Scientific and Industrial Research for the year ending March 31 last. But an announcement of more than ordinary interest, not only to the engineer, but to the whole world in general, is that research on coal has been so successful that a large proportion of coal substances can now be transformed into liquid fuels. What this really means may not at once seem clear, but it will be better appreciated, especially by the motorist, when it is made evident that at least 80 gals. of motor spirit can be obtained from 1 ton of coal. It is hoped that 120 to 130 gals. will be obtained. Experiments in this direction have been so successful that a company is already working to develop the process on a commercial scale. Not only will this new development be of immense value to the coal trade, but it will be useful as a reserve for the country to fall back on at any time, in the event of a shortage of oil.

Shipbuilding Depression on the Tyne.

When Messrs. Vickers Armstrong, Ltd., launch the liner *Monarch of Bermuda* from their Walker yard on March 17, only two shipyards on the Tyne will be left with vessels on the stocks. These will be the Wallsend yard of Messrs. Swan, Hunter and Wigham Richardson, and that of Messrs. Hawthorn, Leslie and Co., Ltd., at Hebburn. The first-mentioned firm is building a number of tankers and a floating dock for New Zealand, while Messrs. Hawthorn, Leslie have two vessels on the stocks. Not another order is on hand on the Tyne, except the two new destroyers to be built by Palmers' Shipbuilding Co., Jarrow. The *Monarch of Bermuda* is a luxury liner of 22,000 tons, built to the order of Furness, Withy and Co., Ltd.

International Aluminium Competition.

In connection with the International Aluminium Competition promoted by the International Aluminium Bureau, with prizes totalling £800, we would again remind competitors that the final date for the sending in of particulars of inventions is April 1, 1931. Particulars should be sent, before this date, to: Bureau International de l'Aluminium, 23 bis Rue de Balzac, Paris, 8, from whom all information regarding the competition can be obtained.

Some Contracts.

The Southern Railway Company has placed an order with William Denny and Brothers, Dumbarton, for a twin-screw geared turbine steamer for the company's Channel Island service.

Two contracts are announced for repairs to recently damaged vessels. The Mountstuart Dry Docks, Ltd., are to repair extensive shell and other damage on the French steamer *P.L.M.* 14, which was in collision recently; while repairs to the Cardiff steamer *Glenarch*, which went ashore in Ireland in January, are to be carried out by the Ailsa Shipbuilding Company, Ayr.

John Brown and Co., Sheffield, have received orders for 700 tyres, 76 nickel steel axles and 24 pairs of tyred wheels and axles for a tramway system in Monte Video; a quantity of springs for the Buenos Aires Tramways; 1,250 beater-bars for threshing machines in South America; and steel bars for the War Office.

The Admiralty have placed the following contracts: Nickel-steel cylinder-head bolts—Thomas Firth and Sons, Sheffield; and boiler plates—the Park Gate Coal and Steel Company, Rotherham.

The Crown Agents for the Colonies have ordered steel tyres from Samuel Fox and Co., Sheffield, and from Baker and Bessemer, Rotherham; and water-tanks from Newton, Chambers and Co., Chapeltown, Sheffield.

The Vulcan Motor and Engineering Company (1900), Ltd., Southport, have received orders from the Plymouth Corporation, for ten 3-ton refuse collectors, and from the St. Marylebone Council, for six 30-40-cwt. refuse collectors.

L. J. Speight, Ltd., Kingsway, W.C. 2, has secured a contract from the Peterborough County Council, for the construction of road bridges over the river Nene and the L.N.E.R., to replace a level-crossing known as Fletton Crossing, near Peterborough (East) station. The value of the contract is £101,368, of which the Ministry of Transport will contribute 75%.

In connection with ventilation improvements in Rotherhithe Tunnel, under the Thames, the London County Council have placed the following orders:—Eight electrically-driven exhaust propeller fans—James Keith and Blackman, Co., Ltd., Farringdon Avenue, E.C. 2 (£2,234); two centrifugal blowing fan sets—Harland and Wolff, Ltd., N. Woolwich, E. 16 (£2,503); eight steel lattice girders—George Pauling, Ltd., Wimbledon, S.W. 19 (£2,337).

John Fowler and Co. (Leeds), Ltd., Leeds, have received an order for an industrial-type locomotive for Petters, Ltd., Yeovil. It will be fitted with a Petter high-speed atomic Diesel engine.

The following orders have been placed by different railways for steel rail chairs: The Tees-side Bridge and Engineering Works, Ltd., Middlesbrough—3,000 tons for the L.N.E.R., and 1,000 tons for the L.M.S.R.; Head, Wrightson and Co., Ltd., Thornaby-on-Tees—5,000 tons for the Southern Railway; and Pease and Partners, Ltd., Middlesbrough—5,000 tons for the L.M.S.R., and 5,000 tons for the Southern Railway.

A contract has been placed with the Stanton Ironworks Co. for the supply of 16 miles of iron pipes for the transmission of coke oven gas from Clay Cross and Blackwell, Derbyshire, to the Belper Gasworks of the Derby Gas Light and Coke Co. The pipes will be of 12 in. and 15 in. dia. made on the "spun" principle and fitted with flexible joints.

Messrs. A. and J. Inglis, Ltd., Glasgow, have been awarded a contract for the painting of, and repairs to, the L.N.E.R. steamers: *Waverley*, *Marmion*, *Kenilworth*, *Talisman* and *Lucy Ashton*. The steamer *William Muir*, belonging to the same railway company is to be overhauled by the Grangemouth Dockyard Co., Ltd., Grangemouth.

An order has been placed with the Staveley Coal and Iron Co. for the supply of cast-iron pipes for the Royd Moor (Barnsley) water scheme. The contract is valued at £36,000.

Morris Commercial Cars, Ltd., Soho, Birmingham, have received the following orders: One 10-cwt. van for Viscount Lymington, M.P., Farleigh Wallop, Basingstoke; one 30-cwt. station 'bus for the Earl of Kilmorey, Mourne Park, Newry, Co., Down; one "R" type shooting brake for the Right Honorable the Earl of Bradford, Weston Park, Shifnal; and one 30-cwt. lorry for the Marquis of Downshire, Easthampstead Park, Bracknell, Berkshire.

The Mirrlees Watson Co., Glasgow, have secured the following two contracts: Two vertical spindle pumps, each to deal with 72 tons of sewage per minute against a head of 24 ft., and one larger pump for 108 tons per minute, for the Sewage Department of the London County Council; and four vertical spindle pumps each to handle 10,000 gallons per minute against a head of 40 ft., for the Calcutta Electric Supply Corporation.

The Great Western Railway Co. have placed the following contracts: Supply and delivery of water-meters at South Wales ports, George Kent, Ltd., Luton; overhaul of triple-screw steamer, *St. Andrew*, C. H. Bailey, Graham and Co., Barry; extension of engine sheds at Plymouth, E. C. Jordan and Sons, Newport; 30 sets of engine tanks and bunkers for 30 2-6-2 T engines, Ruston and Hornsby, Ltd., Lincoln; work in connection with the rebuilding of the General and Riverside Stations at Cardiff, Christiani and Nielson, Westminster, S.W. 1, A. Jackaman and Son, Ltd., Slough, Bucks., and Ernest C. Jordan and Son, Newport.

Anderson, Grice and Co., Carnoustie, Scotland, have been awarded a contract by the Chesterfield Corporation for the supply of a 7-ton electric derrick crane and fittings.

Chesterfield Electricity Committee has awarded a contract to George Ellison, Ltd., for the installation of switchgear equipment at their generating station.

The Manchester Corporation Sub-Committee has awarded a contract to Messrs. Banister Walton and Co., Ltd., Trafford Park, Manchester, for the steel frame construction of the new reference library and town hall extension building. About 2500 tons of British steel will be involved.

It is reported that the Hungarian railways have entered into an agreement with the Associated Electrical Industries, Metropolitan-Vickers, Ltd., and the British Thomson-Houston group for the electrification of the Hungarian stretch of the Budapest-Vienna main line. The cost, inclusive of electric locomotives, is expected to amount to £1,750,000.

The British Insulated Cables Co., Prescot, has obtained a contract for the supply of cables to the County of London Electrical Supply Co. to the value of £100,000.

A contract has been awarded to George Longdon and Sons, Sheffield, for the construction of the first section of the new steelworks at Ecclesfield of Messrs. Hall and Pickles.

Ruston-Bucyrus, Ltd., Lincoln, have secured a contract from Arcos, Ltd., for the supply of 23 excavators to be used in building operations in Central Russia. The machines are to be of two types, some for steam and some for Diesel-engine operation, and will be of sizes up to 3½ cub. yds. capacity. The value of the contract is about £100,000. Seven other excavators are to be supplied by a Hull firm for the same purpose.

Richard Dunston, Ltd., of Thorne, are to construct a pontoon to carry pile-driving equipment for use in connection with the new fish dock at Grimsby.

Sir Robert McAlpine and Sons, 50, Pall Mall, S.W. 1, have secured a contract for the main engineering work in connection with the extension of the London Underground Electric Railways' line from Stamford Brook Station to Acton Town Station. This is the third section of the proposed extension of the Piccadilly tube railways westwards from Hammersmith to Northfields. The other two sections are being constructed respectively by Balfour, Beatty and Co., Ltd., Queen Street, E.C. 4, and the Underground Electric Railways themselves. James Carmichael (Contractors), Ltd., Trinity Road, S.W. 18, are to construct new sub-station buildings at Northfields and North Ealing, and to extend the existing sub-stations at Acton Town and Ravenscourt Park.

Some Contracts—continued.

The following further contracts have been awarded by the Great Western Railway Co. :—Supply of steel girders and other steel and iron work : The Horsehay Co., Ltd., Horsehay, Salop. Overhaul of the twin-screw steamer *St. Julien* : Cammell, Laird and Co., Ltd., Birkenhead. Overhaul of the triple-screw steamer *St. Andrew* : C. H. Bailey, Graham and Co., Ltd., Barry. Combined plate-binding and strengthening rolls for new concentration yard, Swindon : J. Bennie and Sons, Glasgow. Alterations to sheet shop for electrical maintenance stores at Paddington goods station : Willian Brown and Sons (Builders), Ltd., Uxbridge Road, W. 12. Overhaul of the ferry steamer *The Mew* : Willoughby (Plymouth), Ltd., Plymouth. Running shed lathe at Oxford : Dean, Smith and Grace, Ltd., Keighley. Steel girders and other steelwork : Braithwaite and Co. (Engineers), Ltd., Westminster, S.W. 1. Supply of one Butler crank-shaping machine, 20 in. × 22 in. stroke : Butler Machine Tool Co., Ltd., Halifax. Supply and erection of two 1-ton transporter cranes for Park Royal goods shed : Wharton Crane and Hoist Co., Ltd., Reddish.

The London County Council announce an extension of the contracts already placed with various firms for component parts for 150 tramcars. It has been decided to purchase 60 new tramcars of the H.R. 2 class, at a total cost of £182,500. The firms concerned are Hurst, Nelson and Co., Ltd., Motherwell, Lanarkshire, the Metropolitan Vickers Electrical Co., and the Electro-Mechanical Brake Co., Ltd., West Bromwich.

Sir William Arrol and Co., Ltd., Glasgow, have received an order from the Ford Motor Co., Ltd., for one 10-ton overhead travelling electric crane, and another from the County of London Electric Supply Corporation for one 175-ton and one 30-ton overhead travelling electric crane for use in connection with extensions to Barking Power Station.

The following orders have been received by the Associated Equipment Co., Ltd., Southall, Middlesex :—Three repeat orders for "Regent" double-deck buses, for 28, 4, and 10 respectively ; eight repeat orders for "Regal" single-deck buses ; nineteen fresh orders for "Regal" single-deck buses ; five orders for the "Mercury" 3½-ton, eight for the "Monarch" 4-ton, seven for the "Majestic" 6-ton, and thirteen for the "Mammoth" heavy-duty freight chassis.

Marine Oil-Engine Seatings.

At a general meeting of the North-East Coast Institution of Engineers and Shipbuilders on February 27, an interesting paper was read by Dr. J. Montgomerie, Chief Ship Surveyor, Lloyds Register of Shipping. Entitled "Notes on Motor Engine Seatings," it discussed the stresses imposed on oil-engine seatings as compared with those of steam engines.

Dr. Montgomerie first gave a brief review of the development of the application of the internal combustion engine to merchant vessels during recent years. The figures were remarkable, revealing that since 1927 the number of motor ships in the world had increased by 1,000. This rapid expansion in the use of this type of propulsion had created many new problems, both for the engineer and for the shipbuilder. One of these problems was the form and construction of motor-engine seatings, in regard to which practice had been based on the experience gained from steamers. Motor engines, however, were heavier and of greater height, and, therefore, there was a greater range of stress fluctuation in the holding-down bolts, and greater variation in the horizontal forces acting on the structure.

He then gave details of ten cases in which trouble of some sort had developed in the seating of marine engines, in each case describing (with the help of diagrams), the method by which the trouble was eliminated. With these results in view, he concluded by suggesting the following general principles which should be applied to the design of engine seatings in order that they may be relied upon satisfactorily to fulfil the functions for which they have been designed : (1) the top plates should be as broad as possible, to allow for increase in the amount of riveted attachment at the top ; (2) as broad a base as possible should be allowed to the transverse brackets ; (3) the disposition of the girders in the double bottom under the seating should receive every attention ; (4) the thrust seatings and auxiliary seatings should be incorporated as far as possible in the main construction, and, in addition, should reach as far as the bulkheads and be attached thereto ; (5) cross ties between the longitudinal girders are no longer thought necessary ; (6) the highest standard of workmanship is essential.

Catalogues and Other Publications.

A publication of considerable interest to those who follow the progress of steel-making is a new "Treatise on Steels," recently published by British Rolling Mills, Ltd., of Tipton, Staffordshire. This brochure not only contains descriptions and specifications of carbon steels, mild steels, aircraft steels, and other "Brymill" products, but also an interesting article on the preparation and use of casehardening steel. This article is accompanied by illustrations and micro-photographs.

The British Aluminium Co., Ltd., have published a very interesting booklet entitled "Aluminium : Its Production, Properties, and Application." On alternate pages are fine photographs illustrating the text, and showing every sphere in which aluminium is used. We see aeroplanes, motor-cars, airships, tanks, and even statues, in the production of which aluminium plays an important part. Those interested should apply to the above company at Adelaide House King William Street, London, E.C. 4.

The main feature of the "Nickel Bulletin" for February, is an article by H. E. Upton, A.M.I.Mar.E., on "Air, Oil and Water Coolers." This article is accompanied by a number of illustrations, and discusses the influence of design and materials on Cooler service, with special reference to corrosion. In addition to abstracts and references dealing with almost every sphere of the nickel industry, this issue includes an article on "The Non-Toxicity of Nickel," and an appreciation of Captain Sir Malcolm Campbell's recent achievement.

In addition to articles which cover many spheres of the welding industry, the February issue of the "Welder" contains a supplement dealing with the British Industries Fair at Castle Bromwich, where several items of interest relating to the various welding processes were shown. The articles in the supplement include those on the "Oxy-acetylene Welding of Copper by the 'Premag' Process," and "Automatic Arc-Welding by the 'Flexin' Process," of which demonstrations were given daily at the stand of Murex Welding Processes, Ltd. The other articles in the first part of the issue include : "The Design of Welded Steel Structures," "The Welding of a Turbine Cylinder" and "The Fabrication and Welding of H.R. Crown.T.Steel, in Czechoslovakia."

Messrs. Burton Griffiths and Co., Ltd., the distributors in this country of the products of Messrs. B.S.A. Tools, Ltd., have sent us a brochure describing the B.S.A. 6 in. × 6 in. Multi-Tool Production Lathe. This machine corresponds to a smaller edition of the B.S.A. 8 in. × 10 in. Form Turning or Facing Lathe, and can be fitted with different types of head-stocks to suit different work. The brochure contains full details of the general design of the machine, together with illustrations, specifications and a capacity chart.

We have received a list giving particulars of sizes and prices of steel-faced iron regularly stocked by Macready's Metal Co., Ltd. This firm occupy the position of London stockists for Messrs. James Neill and Co. (Sheffield), Ltd., of Sheffield, in connection with the "Bogie" Brand Steel Faced Iron, the steel facing of which is a special tungsten chrome steel, and tools made from it are claimed to outlast considerably those made from straight carbon steel.

We have received a booklet from Imperial Chemical Industries, Ltd., containing an account of the companies, complete lists of all their products and general information regarding the sales departments for each product. It is interesting to note that the company owns 119 factories, and employs approximately 49,000 workers within the British Empire. This booklet is issued from the I.C.I. Head Office, Imperial Chemical House, Millbank, London, S.W. 1.

A recent pamphlet published by the Electric Resistance Furnace Company, Ltd., London, contains a detailed description of the "E F C O" High Temperature Furnace, Type "S." The main feature of this furnace is that non-metallic resister rods are used in it in place of nickel-chromium alloy rods, which cannot be used safely above a temperature of 1,100° C. Special attention is drawn to the simplicity and efficiency of the cooling methods employed.

Mining and Metallurgy "Bulletin."

IN addition to a number of reports on recent discussions, the January issue of the "Bulletin" of the Institution of Mining and Metallurgy contains the subject matter of two papers discussed at a meeting of the Institution at Burlington House, Piccadilly, W., on Thursday, January 15. The first of these, entitled "Ground Movement and Methods of Support in Deep-Mining (the Kolar Gold Field)" by Mr. P. J. Crowle, deals with the subject from an entirely practical point of view, based on several years' experience of deep-mining operations; the subject matter, in this case, is accompanied by a number of interesting illustrations. The second paper, by Mr. G. W. Eaton Turner, is entitled "Losses in Extracting Ore from Mines," and discusses the various ways by which these losses occur—waste, unsuitable material used, and theft being among the chief causes. The reports on recent discussions include those on "The Copper-shale (Kupferschiefer) of Mansfield," by J. W. Gregory, the "Witherite Deposit of the Settlingstones Mines, Northumberland," by G. Trestrail, and "A Device for Controlling Mine Dams," also by G. Trestrail. The "Bulletin" is published by the Institution, Cleveland House, 225, City Road, London, E.C. 1.

The Modern Blast Furnace and its Operation

(*Continued from page* 184.)

that this degree of oxidation amounts to 15% of the whole amount present in the case of iron. Some doubt has been cast upon this, in view of the fact that samples of slag containing more than 1 or 2% of FeO cannot by any method be obtained from furnaces operating normally. The extraction from the vicinity of the "combustion zone" of a slag containing of the order of 50% FeO has been demanded as proof of the assertion.

As Wüst has pointed out, such a proof is unnecessary and impossible, owing to the extremely rapid reduction of practically the whole of the FeO by some of the silicon, manganese, etc., which have hitherto escaped oxidation. It may be that other elements whose oxides are higher up the scale in Table 4, and which do not persist appreciably in the elemental form in the pig iron, are also involved to some extent. The function of such elements as killing agents in steel manufacture provides a parallel case.

In view of the greater affinity of manganese, silicon, phosphorus, etc., for oxygen, it might appear strange that so large a proportion of the iron should be oxidised whilst a considerable amount of these elements remains in the elemental form.

Reference was made in the previous section to the approximate order in which the oxides were reduced. In that case, the most easily reducible oxide (FeO) of those enumerated was present in the largest amount, and provided the greatest opportunity for contact. Thus, other things being equal, the logical sequence followed.

When "re-oxidation" is considered, the element least liable to oxidation of those under review provides the greatest facilities for contact and reaction. Thus, the order of oxidation is thrown out of step momentarily, and not until later are the equilibrium values approached.

It is well established that in the Bessemer process, oxidation of carbon, silicon, manganese, and phosphorus by atmospheric oxygen proceeds via the medium FeO. Re-oxidation in the blast furnace is in many respects a similar case.

S.O.S.

The demand for recent issues of "Metallurgia" has been so great that many issues are now out of print. Requests are continually being received for certain issues to make up volumes, and we would esteem it a favour if any of our readers, who have finished with their copies, are willing to dispose of them. We particularly desire the issues of January, April, June, August, September, October, and November, of 1n30.

Iron and Steel Report.

UNDER normal conditions of industrial activity the iron and steel markets at this time of the year show indications of increased buying interest. On the present occasion this is much less in evidence, although market pointers are in the direction of somewhat brighter conditions than have been experienced during the past three months or so.

A favourable factor in the case of pig iron is that certain of the principal makers in the Midlands have during the past week or two not only met with an expansion of inquiry, but have actually booked orders for a bigger tonnage. Moreover, the fact that users are beginning to acquire a certain amount of confidence in prevailing prices—a much-desired market factor that has been absent for so long—would appear to be indicated by a number of orders for delivery over two or three months which have come to hand. So far, not all the producers of foundry iron have participated in the improved conditions, but the experience related above may be regarded as favourable as far as it goes. What sellers are hoping for is that the spurt, slight as it has been up to the present, will be sustained.

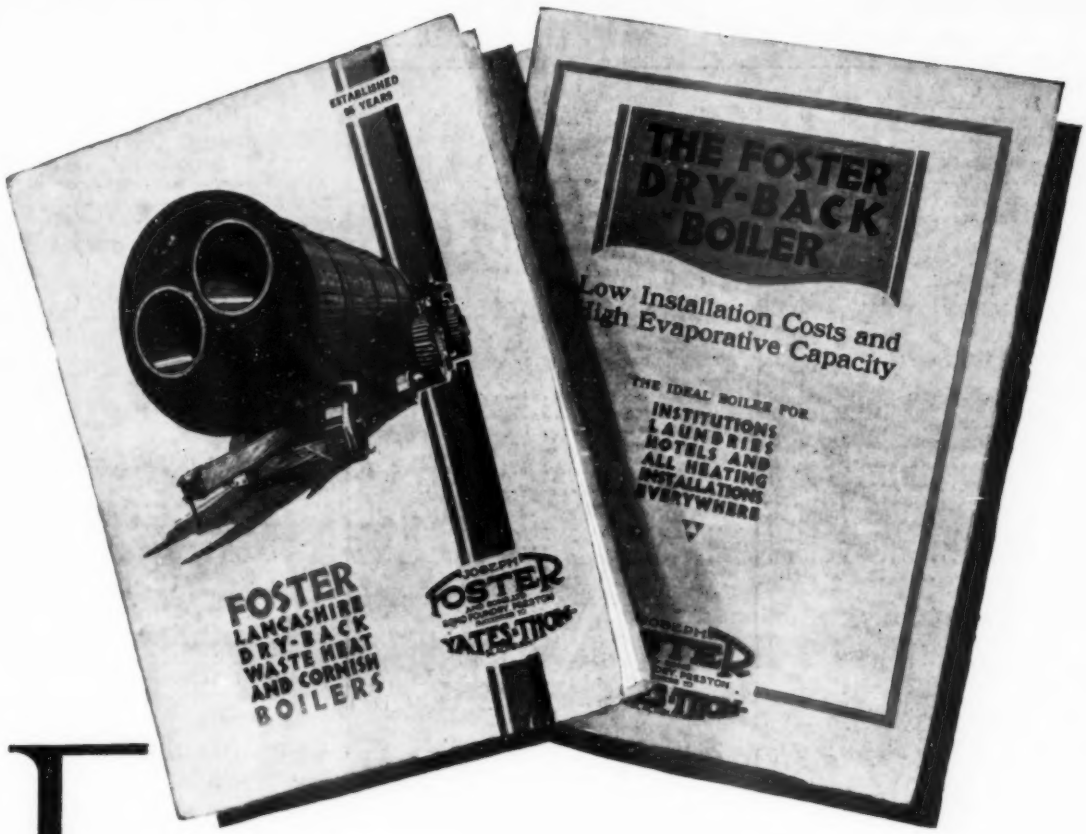
On the North-East Coast, however, producers have not yet struck much better conditions, although here also, inquiry has opened out a little compared with a month ago. The trouble with Cleveland makers, so far as the home market is concerned, is that Continental and Indian competition in certain areas has not yet been effectively scotched, although the recent substantial cut by North-East Coast makers must have gone some way towards easing the position. Midland producers appear to be much better situated in this respect, the sequence of price reductions in Derbyshire, Staffordshire, and other Midland brands of foundry iron having brought quotations down to a level at which very little is heard of underselling by overseas producers. From the point of view of the much-needed market stability, it is satisfactory to be able to record that, apart from minor adjustments at various points, prices have been steady during the past four weeks.

Quotations have also been rigidly adhered to in the case of finished iron, without, however, any appreciable increase in the tonnage being bought. There has been moderate activity in respect of marked bars in some centres, but the nut and bolt-making qualities, in particular, continued to suffer from the formidable competition of the much cheaper Continental materials.

In British steel, the recent adjustment of rebate allowances has not, up to the present, been productive of much real expansion of buying interest, and new contract commitments have been disappointing in most areas. There is still, however, the possibility of a seasonal spurt, though a good deal will depend on the degree of recovery effected in the shipbuilding, constructional engineering, locomotive building, and boiler-making industries, so far as the bulk business is concerned. Apart from a continued easy tendency in boiler plate and rerolled bar prices, the market for British steels generally has been firm.

Several weeks ago a rise in freight rates between Continental and British ports resulted in an upward movement of quotations for imported materials on British markets. It is doubtful, however, whether the rise became really effective, for there has since been evidence of serious undercutting among sellers of Continental steels, with definite renewed weakness in the semi-finished department. Trade with British users in this section of the market has been very moderate indeed.

Two outstanding events of the past month have been steps taken by iron and steel manufacturers in this country to combat competition from abroad. To differentiate British steel from foreign, a national mark for the former has been formally inaugurated, and earlier on publication was made of the correspondence that had passed between the chairman of the Central (Midland) Pig Iron Producers' Association and of the Basic Iron Producers' Association, and the President of the Board of Trade, calling attention to the serious position of the pig-iron industry.



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MARKET PRICES

ALUMINIUM.

99% Purity	£85	0	0

ANTIMONY.

English	£36	0	0
Chinese	24	15	0
Crude	22	0	0

BRASS.

Solid Drawn Tubes	lb.	9¾d.
Brazed Tubes	lb.	11¾d.
Rods Drawn	„	9¼d.
Wire	„	8¼d.
*Extruded Brass Bars	„	5d.

COPPER.

Standard Cash	£46	7	6
Electrolytic	49	7	6
Best Selected	48	5	0
Tough	47	15	0
Sheets	77	0	0
Wire Bars	49	18	9
Ingot Bars	49	18	9
Solid Drawn Tubes	lb.		11d.
Brazed Tubes	„		11d.

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	2	3
‡Ferro Tungsten	„	0	2	0
§ Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
2-4% Carbon, scale 11/- per unit	ton	28	0	0
4-6% Carbon, scale 7/- per unit	„	22	2	6
6-8% Carbon, scale 7/- per unit	„	21	5	0
8-10% Carbon, scale 7/- per unit	„	21	0	0
§ Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 10/- per unit	„	32	5	0
Guar. max. 1% Carbon, scale 13/6 per unit	„	34	12	6
§ Guar. max. 0.7% Carbon, scale 15/- per unit	„	38	17	6
‡Manganese Metal 96-98% Mn.	lb.	0	1	3
‡Metallic Chromium	„	0	2	7
§ Ferro-Vanadium 25-50%	„	0	12	8
§ Spiegel, 18-20%	ton	6	17	6
Ferro Silicon—				
Basis 10%, scale 3/- per unit	ton	5	17	6
20/30% basis 25%, scale 3/- per unit	„	7	0	0
45/50% basis 45%, scale 5/- per unit	„	10	2	6
70/80% basis 75%, scale 7/- per unit	„	17	5	0
90/95% basis 90%, scale 10/- per unit	„	25	6	0
§ Silico Manganese 65/75% Mn., basis 65% Mn.	„	14	0	0
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	6
§ Ferro Phosphorus, 20-25%	ton	15	10	0

FUELS.

Foundry Coke—						
S. Wales Export	£1	2	0	to £1	16	6
Sheffield Export	0	15	0	to 0	16	0
Durham Export	1	6	0	to 1	8	0
Furnace Coke—						
Sheffield Export	0	15	0	to 0	16	0
S. Wales „	0	17	6	to 0	18	0
Durham	0	13	6	to 0	14	0

GUN METAL.

*Commercial Ingots	£50	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	1	0
*Cored Bars	„	0	1	2

LEAD.

Soft Foreign	£ 4	3	9
English	15	10	0

MANUFACTURED IRON.

Scotland—			
Crown Bars	£10	5	0
N.E. Coast—			
Rivets	11	10	0
Best Bars	11	5	0
Common Bars	10	15	0
Lancashire—			
Crown Bars	10	5	0
Hoops	13	0	0
Midlands—			
Crown Bars	10	7	6
Marked Bars	12	10	0
Unmarked Bars		—	
Nut and Bolt Bars	9	0	0
Gas Strip	10	17	6
S. Yorks.—			
Best Bars	11	0	0
Hoops	12	0	0

PHOSPHOR BRONZE.

*Bars, Tank brand, 1 in. dia. and upwards	lb.	1/-
*Cored Bars	„	1/2
†Strip	„	1/0¼
†Sheet to 10 W.G.	„	1/0¾
†Wire	„	1/1¼
†Rods	„	1/0¼
†Tubes	„	1/-
†Castings	„	1/1

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£3	14	0
Foundry No. 1	3	16	0
„ No. 3	3	13	6
N.E. Coast—			
Hematite No. 1	3	9	6
Foundry No. 1	3	1	0
„ No. 3	2	18	6
„ No. 4	2	17	6
Cleveland—			
Foundry No. 3	2	18	6
„ No. 4	2	17	6
Silicon Iron	3	1	0
Forge No. 4	2	17	0
N.W. Coast—			
Hematite	4	8	6
Midlands—			
N. Staffs Forge No. 4	3	6	0
„ Foundry No. 3	3	11	0
Northants—			
Forge No. 4	3	2	6
Foundry No. 3	3	7	6
Derbyshire Forge	3	6	0
„ Foundry No. 3	3	11	0
West Coast Hematite	4	4	6
East „ „	4	1	6

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron	£6	0	0	to £7	10	0
Bars, hammered, basis	£17	10	0	„ £18	10	0
Blooms	£10	0	0	„ £12	0	0
Keg steel	£32	0	0	„ £33	0	0
Faggot steel	£20	0	0	„ £24	0	0

All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£38	0	0
„ Brazier	35	0	0
„ Wire		—	
Brass	27	10	0
Gun Metal	36	0	0
Zinc	6	10	0
Aluminium Cuttings	50	0	0
Lead	12	0	0
Heavy Steel—			
S. Wales	2	7	6
Scotland	2	7	6
Cleveland	2	6	0
Cast Iron—			
Lancashire	2	5	0
S. Wales £2 8 0 to	2	9	0
Cleveland £2 8 6 to	2	11	0
Steel Turnings—			
Cleveland	1	12	6
Lancashire	1	0	0
Cast Iron Borings—			
Cleveland	1	5	0
Scotland	1	12	6

SPELTER.

G.O.B. Official		—	
Hard	£9	15	0
English	13	7	6
India	11	0	0
Re-melted	12	0	0

STEEL.

Ship, Bridge, and Tank Plates—			
Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland	10	10	0
„ „ (Marine) „	10	10	0
„ „ (Land), N.E. Coast	10	0	0
„ „ (Marine) „	10	10	0
Angles, Scotland	8	7	6
„ North-East Coast	8	7	6
„ Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	0	0
Light Rails	8	15	0
Sheffield—			
Siemens Acid Billets	9	10	0
Hard Basic £8 12 6 to	9	2	6
Medium Basic £7 2 6 to	7	12	6
Soft Basic	6	5	0
Hoops	10	5	0
Manchester—			
Hoops	9	15	0
Scotland, Sheets 20 W.G.	9	10	0

HIGH SPEED TOOL STEEL.

Finished Bars 18% Tungsten. Extras	lb.	2/9
Round and Squares, ¼ in. to ½ in.	„	3d.
Under ½in. to ⅝ in.	„	1/-
Round and Squares 3 in.	„	4d.
Flats under 1 in. × ⅛ in.	„	3d.
„ „ ½ in. × ¼ in.	„	1/-

TIN.

Standard Cash	£121	7	6
English	123	0	0
Australian	122	17	6
Eastern	125	5	0
Tin Plates I.C. 20 × 14	box		15/6
Block Tin Cash	£122	7	6

ZINC.

English Sheets	£21	0	0
Rods	24	0	0
Battery Plates	16	10	0

* McKechnie Brothers, Ltd., quoted March 10. † C. Clifford & Son, Ltd., quoted March 10. ‡Murex Limited, quoted March 11.

Subject to Market fluctuations, Buyers are advised to send inquiries for current prices.

Lancashire Steel Corporation's Current Basis Prices :—Wrought Iron Bars, £10 5s. 0d.; Mild Steel Bars, £7 2s. 6d.; Wrought Iron Hoops, £12; Best Special Steel Baling Hoops, £8 15s. 0d.; Soft Steel Hoops (Coopers' and Ordinary Qualities), £8 0s. 0d. to £8 5s. 0d; C. R. & C. A. Steel Hoops, £11 10s. 0d. to £12 0s. 0d; "Iris" Bars, £8 15s. 0d. All Nett Cash. Quoted March 10.

§ Prices quoted March 11, ex warehouse.